April 2012

Renewable Energy Burning Cookstove and Surface Environment

Nicholas J. Knight
Worcester Polytechnic Institute

Electrical Subsystem for the

Renewable Energy Burning Cookstove and Surface Environment (REBCE)

A Major Qualifying Project Report:

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Nicholas Knight

Approved:

Professor Robert C. Labonté, ECE Major Advisor

Date: 5/7/12

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Executive Summary

This major qualifying project designed and implemented a stove that can run off wood burning and other burning materials as well as electricity. In addition to the design of the stove, an electrical control system was implemented to increase efficiency as well as to monitor the stove. Gas sensors and temperature sensors around the stove allow for proper monitoring and allow for the stove to be automatically controlled via DC motors that control the airflow through the stove. Overall, the efficiency and the functionality of the stove are a great improvement over what currently exists on the market.

For the purposes of submission, the project report was divided into two parts one for the overall project and another for the electrical subsystem.

The design of the electrical subsystem is adequately flexible to accommodate the design requirements of the overall cookstove implementation.

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Acknowledgements

There are several people that without which this project would not have gotten as far as it did. The first person to be thanked is Professor Mustapha Fofana without whom this project would not have existed. Another that helped immensely with the structure and guidance of this project is Professor Robert C. Labonté. I would also like to thank Jeff Hook who helped with organizational techniques and the location of various electrical devices that would allow easier interfacing of the overall system. Finally, my thanks go to Ramsey Abouzahra who provided information about processor programming and functionality.

I would also like to thank the staff of both the ECE and ME departments who made this project possible.

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1.0: Introduction

Throughout the world, approximately two million annual deaths are attributed to smoke inhalation due to poorly ventilated or unventilated combustion used for cooking. These deaths are most heavily concentrated in third world nations as well as impoverished regions, and unfortunately, they are all completely preventable. Cooking conditions for these areas usually involve dwellings completely filled with smoke from an open fire, with the family still inside. The current cookstove technology ranges from three stones around a fire, to homemade wood stoves, which are usually unsafe in terms of ventilation and thermal insulation. The inefficiency of these systems along with improper fuel selection results in incomplete combustion, generating millions of tons of carbon emissions each year. Carbon emissions produced by people cooking with solid fuels is still a large contributor to the increasing amounts of greenhouse gasses in our atmosphere. Overall, a large portion of the world still does not have the safe, clean, and energy efficient standards of cooking as more developed nations are accustomed. This brings about a negative impact on general health, as well as the environment.

The goal of this project is to develop an affordable cookstove that is safe, reliable, energy efficient, and adaptable to various renewable and conventional fuel sources. The end user of this product can only afford to pay a few hundred dollars on a commercial wood burning cookstove, therefore the product needs to be designed for a cost of under $500. The product needs to be resilient and maintainable, utilizing intuitive design and standard components, because the end user cannot afford to buy a new stove should the cookstove fail. The product needs to be safe in terms of monitoring levels of harmful emissions in the dwelling and alerting the user of hazardous conditions. The cookstove should also be properly thermally insulated, with the exception of the heating element, so the user or a child will not be severely burned upon making contact with the outer surfaces of the stove. The cookstove needs to be well ventilated to prevent harmful emissions from entering the dwelling. The product needs to induce more complete combustion to reduce harmful emissions and increase efficiency. Because electricity is an energy source limited to developed nations, and consumer batteries are an expensive and inefficient method of power, the cookstove needs to be capable of powering its system without a readily available electrical source. Oils and natural gas are expensive fuel sources with limited availability to the targeted end user. Therefore, the cookstove needs to be capable of combusting the various fuel sources available to a region, including bio-mass, wood, wood pellets, and fire logs. Overall, this product should save the end user money by reducing fuel usage and increasing energy efficiency. Affordability will be achieved by proper selection and effective use of materials and components, as well as reducing operating costs for the user. Safety will be achieved by reducing fire and injury hazards, monitoring harmful gas levels, and implementing an effective ventilation design. Fire and injury hazards will be reduced by proper insulation of the cookstove. Hazardous emissions will be monitored through an embedded computer system. Effective ventilation will be achieved by proper design of the cookstove flue. Energy efficiency will be achieved by increasing complete combustion in the firebox, which in turn, will also reduce harmful emissions. Reliability will be achieved with a sturdy structural design with resilient materials, and the selection of reliable and efficient electrical components.

In the next chapter, I will discuss current cookstove designs, emissions data of various fuel sources, and the electrical components of the embedded safety and control system. In chapter three, I will discuss the design and implementation, as well as the analysis and results of various components of the cookstove. Finally, chapter four will discuss our conclusions about various functions and constraints, along with our recommendations for improvement.

2.0: Background & Requirements

The electrical portion of this project will ultimately function as a monitoring, warning, and control system. This portion of the project is necessary to improve the fuel efficiency as well as the safety of the cookstove. The system will achieve its goal of regulating burning temperatures by monitoring temperatures of the inside and outside of the stove. By keeping track of the temperatures in and around the stove, the electrical subsystem will regulate these by using a geared dc motor to control the overall air intake. The system will also be able to control heating coils for stovetop and oven cooking. The electrical subsystem will also employ LEDs and a buzzer to inform the user about unsafe levels of harmful gasses around the stove. The system will also have an LED to indicate there is combustion happening in the stove. The user will be able to adjust the temperature of the stove with up and down arrow buttons. Finally the electrical system will have an LCD screen to provide the user with some basic information such as temperature of the cooktop, cooking timer and burning and igniter fuel indicators. Overall all of these features will be necessary in order to make the stove as easy to operate as pushing a button or turning a knob and will ultimately make the stove much safer and fuel-efficient.

The stove is to be capable of working with burning materials as well as electricity. If the consumer has access to electricity they can use the stove with the electrical coils for cooking instead of burning materials or even use both at the same time for faster cooking. This will not only decrease the output of more harmful gasses but also decrease the time it takes to cook a meal. Since electrical coils heat quickly, waiting time will be reduced and cooking time decreased. In addition to having electrical coils as well as a combustion chamber increases the marketability of the stove to anyone who wants the versatility. Overall, having a stove that can function on both electricity and burning materials is a substantial part of the justification for the market of the stove.

The electrical system will have to be capable of running off a small amount of electricity generated either by a small solar panel or the heat of the stove. The heat of the stove can be converted into electricity in many different ways, however two ways have proven to be the most feasible for this project. The first of the ways of converting the heat of the stove into electricity is to use a Stirling engine that would push a magnetic piston through coils of wire in a linear motion. This idea comes from the simple hand-powered flashlights that are shaken to generate electricity to power the flashlight. The second way of converting the heat to electricity is to use an electrical device called a TEG (Thermoelectric Generator) module, which is done by a process called the

"Seebeck Effect" that converts temperature differences between two thermal plates directly into electricity. Solar panels are also a considerable power option however solar energy is inconsistent and would therefore require some battery storage that increases the overall price of the project. Finally we considered wind power however this is both inconsistent and considerably more expensive than the other options considered due to the high precision and tolerances in the manufacturing of the moving parts. Overall The TEG modules or solar panels would be preferable since they are solid-state devices thus decreasing the noise and maintenance costs. Using a Stirling engine requires moving parts, which can mean breakdown of the stove and this is not acceptable since the end user may not have the funds or the means to repair it.

The system will use feedback loops in order to regulate temperatures inside the stove better and better over time creating the optimal hysteresis loop just as a thermostat does. This temperature control will be achieved by monitoring the differences between the desired and actual temperatures as well as movement of the motor controlling the air intake. As the system runs for more uses and even as humidity changes it will be able to adapt by constant monitoring and adjusting.

In order to achieve all of the functionality described, the system will use a microprocessor. The choice of the microprocessor will be determined in part by the availability of power generated by the Thermoelectric Generator (TEG) modules. It will also have to be fast enough to achieve all the monitoring, controlling and reporting in a timely fashion. Finally the microprocessor must be an affordable model as the overall stove design cannot cost any more than $500 USD to the consumer. For design purposes an Atmel microprocessor from the ATmega32 series was selected for building and testing. This Atmel device can be replaced with a more inexpensive, and energy efficient microprocessor in the manufacturing stage.

Several TEG modules have been examined for powering the electrical subsystem. The first of the modules is the TEP1-1264-1.5. This module generates 8.6V_{OC} (Volts Open Circuit) with a hot side temperature of 230°C and cold side temperature of 50°C. With this output voltage and output energy of about 5.4W this device should provide adequate power for the electrical subsystem. Two additional were examined: the TEP1-12656-0.8 and the 0.6. These two modules produce open circuit voltages of 8.7V and output wattages of 10.5 and 14.7 respectively. Overall the TEP1-1264-1.5 is the most cost effective for the application and is recommended for the final design.

During the research into designing the electrical control and safety system one project/product that is similar and could be considered competition for our cookstove design was discovered. The stove found in researching was designed by a team of engineers in Nepal and is called the Batho Chulho [1], which means smart cookstove in Napalese. The Batho Chulho can be seen below in a breakdown view(Figure 1). This stove uses a microprocessor system to control a flue vent that regulates airflow and control the burning temperature. The Batho Chulho also has an LCD display with indicators to the cooking mode. This consists of multiple temperature ranges of the stove and a knob to increase or decrease the temperature. The LCD panel also displays a cooking timer controlled by a cooking time knob. It also indicates igniter and burning-fuel levels, as well as battery-power level. Finally the system includes a power LED to inform the user that combustion is occurring inside the stove. The Batho Chulho stove is estimated to cost around $37.50 and has an operating cost of around $0.15 per briquette. These briquettes are estimated to last for two cooking sessions for a family of 5 people. There is also operating costs of $1.50 and $1.00 every 2 months for a battery, and lighter respectively [1].

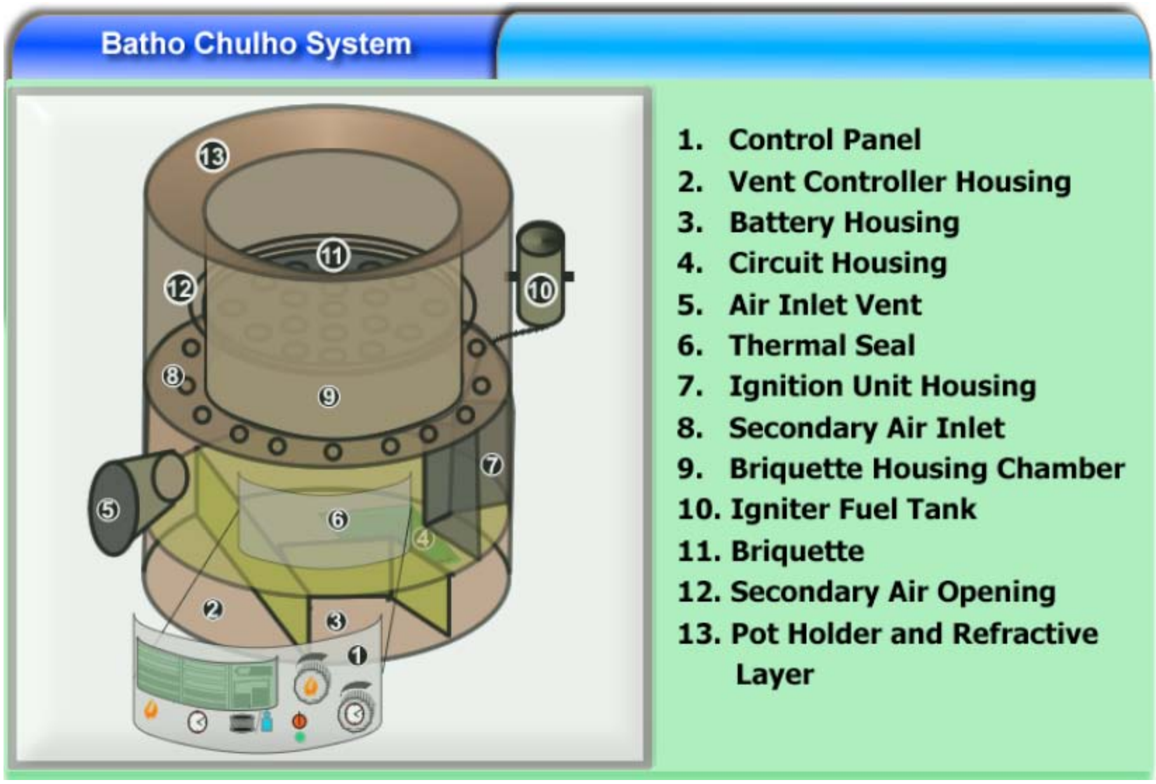


Figure 1: Breakdown View of the Batho Chulho [1]

Although the Batho Chulho is much less expensive, it does not include all of the added functionality and safety measures that our project cookstove will require. Specifically, the Batho Chulho lacks a harmful gas monitoring and reporting system. Safety is a very important element for this project since one of the biggest concerns is to keep the user safe while they are using the stove. The Batho Chulho also lacks the ability to exhaust smoke from the stove any faster than the air flowing through it. In comparison the stove that is being designed for this project will have a large size ducting sufficient for the ventilation of any gasses being formed. Finally the Batho Chulho is a much smaller stove than the REBCE and is only a single burner with no oven making cooking for a large group difficult. Overall the REBCE should have an advantage over the Batho Chulho since it has some added safety features, more ways of increasing the burning efficiency, and can cook for a large family.

3.0: Design and Implementation

3.1: Design Overview

The design of this system has been mapped-out into an easy to understand block diagram (Figure 2). It can be seen in the diagram that the center of the system is the microprocessor. To the left of the microprocessor is the power system including wall power and the TEG modules along with the battery-charging circuit. To the top of the microprocessor are all of the various sensor inputs including gas sensors, thermal resistive sensors, and potentiometers. Finally, all of the outputs of the system are shown below the microprocessor and include: the LCD screen, LEDs, DC motors, and a buzzer. All of these elements of the electrical subsystem are described in more detail in the implementation section that follows.

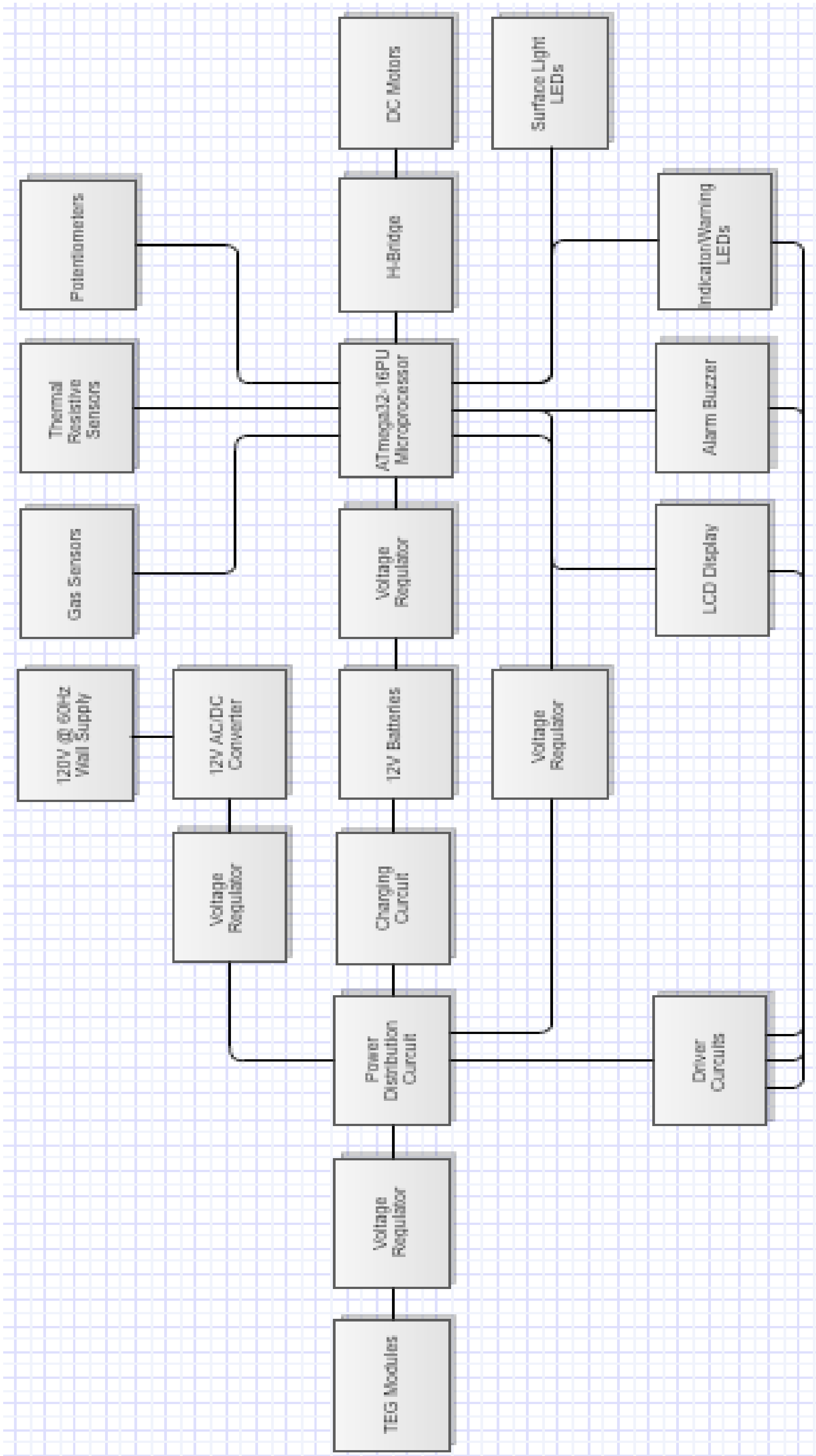


Figure 2: Circuit Design Block Diagram

3.2: Implementation

3.2.1: Processor

The processor that is being used to implement this design is the ATmega32-16PU. This is an 8-bit AVR processor manufactured by Atmel. The processor is set onto an Olimex development board that has voltage regulation onboard and can be powered by either 9-12V DC or 6-12V AC. The development board also has an LED, a single button, RS232 port, and JTAG connector. The JTAG connector is connected through USB via a programmer that converts USB to JTAG. The software code involves interfacing with various I/O devices as well as feedback loops between the temperature sensors and the vent-controller motors. In the aggregate these form the hysteresis loop which will regulate the temperature of the stove. For programming software IAR kickstart for AVR processors as well as another freeware program called AVRstudio 5.0 are being used. IAR kickstart can program the board directly while AVRstudio 5.0 requires a secondary program called WinAVR to download the compiled code. While both programs work fine for programming of our ATmega32 AVR processor, IAR kickstart does not include the library of header files for use by the processor. As a consequence it was more difficult to get files downloaded to the microprocessor. Both systems are capable of programming the AVR processor through the USB programmer. The development board and USB programmer can be seen in the diagram below (Figure 3).

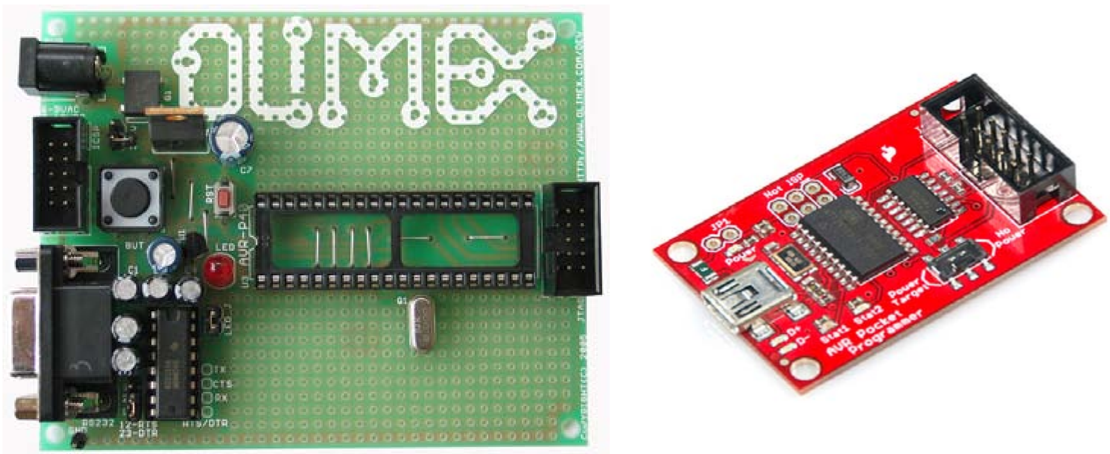


Figure 3: Olimex 40 Pin Development Board (left) and USB Pocket Programmer (right)

For design purposes and due to time constraints, an MSP430 was used to design and test the functionality of the electrical control system. The code for this processor is provided in the appendix of this report. These processors are designed for very low power consumption and are readily available for use in the ECE laboratories. The functionality requirement of the code is to read potentiometer and thermistor values and control a DC motor that opens and closes the air intake valve of the stove.

3.2.2: Power System

The power system is comprised of several components. These include: an AC/DC converter for DC power obtained from a wall outlet, AC and DC voltage regulators, Thermoelectric Generator modules, and Battery Storage. There is also power distribution portion in order to be able to charge the batteries at the same time as running the control system.

3.2.2.1: Wall Power

In order to utilize 120V, 60Hz wall power an AC/DC converter circuit is required to regulate the wall power down to 5VDC. This AC/DC converter circuit has not be implemented in this MQP due primarily to time and design requirement constraints. However, if needed an AC/DC converter by ROHM part number BP503405 would be used to convert the wall power down to 5VDC. 5VDC is adequate for powering the processor and all of the I/O devices of the prototype. In the final design implementation, however, will require a circuit to be designed that is capable of supplying slightly over $1A_{max}$ for the entire system. At that level there should be enough energy to run all I/O devices simultaneously.

3.2.2.2: Thermo-Electric Generation

In researching renewable energy sources devices called TEG modules were found. These modules utilize a process called the "Seebeck Effect", a process which turns a temperature differential across two ceramic plates into electricity through NPN junctions. The modules were tested on top of an electric range sandwiched between two heatsinks. The two modules were wired in series and tested, producing a maximum of about 4.2VDC. Consequently, it is expected that an array of six of these modules can be expected to achieve adequate power for the entire system. The six of these modules will be placed on one of the burn chamber walls and will have heatsinks on the opposite side to keep the temperature differential as high as possible. Because the voltage output of these modules can vary and is not always producing current we need both battery storage as well as voltage regulation to charge the battery storage cells at a constant voltage. In some cases a battery charging circuit will also be required but can easily be purchased as an IC along with some battery cells.

3.2.2.3: Voltage Regulation

As mentioned above, the output voltage of the TEG modules is not always consistent as it is a function of the temperature differential between two ceramic plates. In order to regulate this voltage to a constant supply a DC voltage regulator is required to charge a battery or provide voltage to a charging circuit.

While not a requirement for this prototype design, a small voltage regulator IC, as well as some additional circuitry will be designed to properly divide the power so that the battery can be charged while the system is being run.

3.2.2.4: Battery Storage

When adequate energy is not available from wall power, battery backup that is charged by both the TEG modules and wall power will be utilized to power the system. This will allow the circuit to be functional even when wall or heat power is not available for a period of time, until the stove heats up again or wall power is reestablished. In order to allow the batteries to charge, power must be distributed correctly so the system can be run at the same time as charging.

3.2.3: Sensor Inputs

As described below, the system will include multiple sensor inputs. The sensors that will be used in this system include various gas sensors, thermal resistive sensors, and potentiometers.

3.2.3.1: Gas Sensors

This project will include various gas sensors including: carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitric oxide (NO), and nitrogen oxide (NO_2). All of these gas sensors will be connected to and monitored by the Analog to Digital Converter (ADC) of the microprocessor. Interrupts to the microprocessor will trigger if any of the levels on any of the sensors reach a certain threshold. This threshold for each gas will be the corresponding ppm at which the gas becomes dangerous and toxic to the individual breathing it in. All of these sensors will be placed around the cookstove, as that is the area we want to ensure has good air quality. If all the sensors are found to be within safe levels then the area is safe for cooking, however upon reaching any unsafe levels the microprocessor will sound a loud beeping buzzer alerting the user to evacuate the area. The microprocessor will also shut off airflow to the stove causing the fire inside the burn box to extinguish. Overall the gas sensors will ensure the user is not breathing any harmful gasses while cooking.

3.2.3.2: Thermal-Resistive Sensors

This design component includes various temperature sensors that will also be read by the microprocessors ADC circuitry. These values, once calibrated will allow the microprocessor to determine how much to open or close the air intake valve in order to reach the right temperatures on the stovetop and inside the oven. These sensors will be placed at various points around the stove and shielded to ensure they are not exposed directly to any open flames.

3.2.3.3: Potentiometers

The system will include various potentiometers: two to control the stovetop heating coils, and one for control of the oven temperature. These controls will work by being calibrated with the ADC of the microprocessor and the lowest and highest settings of each potentiometer will correspond to all-the-way off up to full heat.

3.2.4: Outputs

The system will include various outputs in order to communicate certain things to the user. These outputs will be explained further below and will include: LCD screen, Feedback LEDs, DC motors, and a buzzer.

3.2.4.1: LCD

The LCD screen in this project is used to display the oven temperature as well as a clock and cooking timers. The LCD screen being used for this project is a small black and white 8-bit device. The LCD screen chosen for the system has internal memory to store 8-bits of data. The screen is communicated to by 8 parallel bus lines by the processor in a sequence of 8-bit pages. The LCD screen then prints page-by-page to the 128x32 pixel screen starting in the top left and moving to the right and down as a book would be read. The LCD screen also includes a backlight feature so the clock can be seen at night.

3.2.4.2: LEDs

This system includes multiple LEDs for various functions. First there will be bright-white LEDs mounted above the cooking surface in order to allow for nighttime cooking. There will also be a red LED to indicate that the stove is hot and warns the user not to touch it. Finally there will additional LEDs that will be illuminated to notify the user if the gas sensors determined values exceed their thresholds which indicate what gasses have been detected.

3.2.4.3: DC Motors

For oven heating and cooling, dc motors are included in the project to demonstrate the opening or closing of valves throughout the stove. The DC motors have gear ratios such that the arm will have adequate torque and low RPMs to ensure accurate positioning when opening or closing of the valves. In the final design, a motor with an RPM feedback line is used in order to determine how accurately opening or closing the valve is achieved. The motors are connected in an H-Bridge configuration so that switching of voltage across the DC motors reverses the polarity and allows the motors to spin in both directions.

3.2.4.4: Buzzer

As mentioned above in the gas sensor section, a buzzer will be implemented in order to notify the user of any unsafe conditions being experienced by the stove. In order to ensure that the buzzer is loud and piercing enough, the buzzer will have a sound pressure level of 80dBA @ 12V and 0.1m and a frequency of over 2kHz. The buzzer chosen has an internal crystal oscillator and therefore needs only to be provided with a DC voltage to be operated. In order to make the buzzer even more noticeable, it will beep rather than just staying on constantly and will go off when the gas levels are back within a safe range.

4.0: Project Overview

For this project, all of the essential functionality described in the design and implementation sections above have been included in the hardware and software of the electrical subsystem. Once the mechanical design of the overall system has been completed a more fully functional electrical system will be implemented. A fully functional electrical system will be implemented in prototype form to achieve the full functionality required by the cookstove. For example, potentiometers will be monitored in order to decide the range of control required to achieve full functionality. In addition, the relationship between the values of the potentiometers and thermal resistive sensors will be determined. At the same time, development of the prototype electrical system should include the electrical power circuitry required by the system.

The diagram shown below (Figure 4) indicates which parts of the electrical system have been implemented for this MQP. The block diagram shown below is color coded. The green squares are the components that were implemented for this MQP, the orange squares are the ones that may be implemented if time permits, and the red squares are the components are that will not be implemented for this MQP. The block diagram below is similar to the one provided in the design overview section of chapter 3 with the exception that it has color coded squares to indicate what the goals of this MQP are.

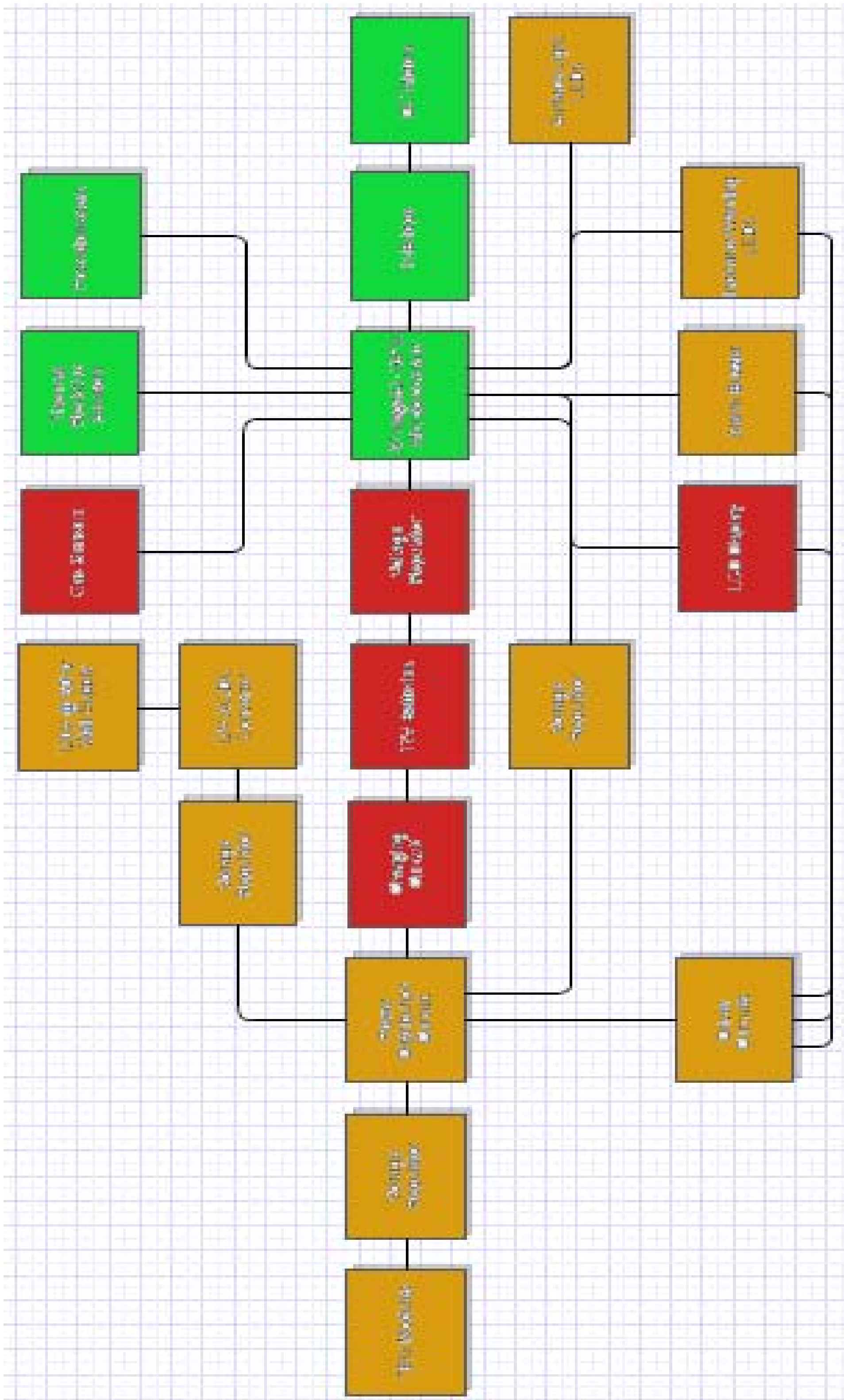


Figure 4: MQP Goal Block Diagram

An overall parts list for all the components used for this MQP can be seen in the excel spreadsheet below (Figure 5). The cost of all the parts is approximately $150.00 and is under $100.00 at the bulk prices.

Part Description	Price	Bulk Price (100+)	Part Number	Quantity
Processing				
ATMEGA8515-16PU-ND	$3.87	$2.16	96K6517	1
Inputs				
Resistance Temperature Detector	$13.82	$1.53	615-1045-ND	3
Methane Gas Sensor	$3.90	$2.90		1
Carbon Monoxide Sensor	$8.90	$6.90		2
Air Quality Control Sensor	$6.90	$4.90		1
Outputs				
Red LEDs	$0.07	$0.07	L53HD-ND	10
Green LEDs	$0.18	$0.08	754-1262-ND	10
Bright White LEDs	$1.69	$1.45	365-1507-1-ND	3
LCD display	$11.00	$7.92	NHD-C12832A1Z-	1
Buzzer	$3.55	$1.68	668-1204-ND	1
DC Motors	$3.25	$2.27	P14354-ND	4
Power				
TEG Module (TEPI-12709)	$1.00	$1.00		1
Battery	$13.64	$10.59	5169-UBP001	2
Battery Charging IC	$7.25	$3.63	296-9356-5-ND	1
AC/DC Converter (120 VAC - 5 VDC)	$6.25	$3.13	BP5034D5-ND	1
Totals				
Total Green	$121.23	$59.22		
Total Red	$29.60	$22.60		
Sub Total	$150.83	$81.82		

Legend
Order
Don't Order

Figure 5: Parts List for MQP parts

Finally, the overall circuit diagram for the system can be seen below (Figure 6) and illustrates how each of the components is wired to the processor. The processor can be seen in the center, TEG modules to the right and the AC power source just above the processor. The thermistors at the top represent the gas sensors. The LCD module, buzzer, and the warning and surface lighting LEDs are included to the right. Finally we have the motor, keypad, and power switch just to the left of the processor.

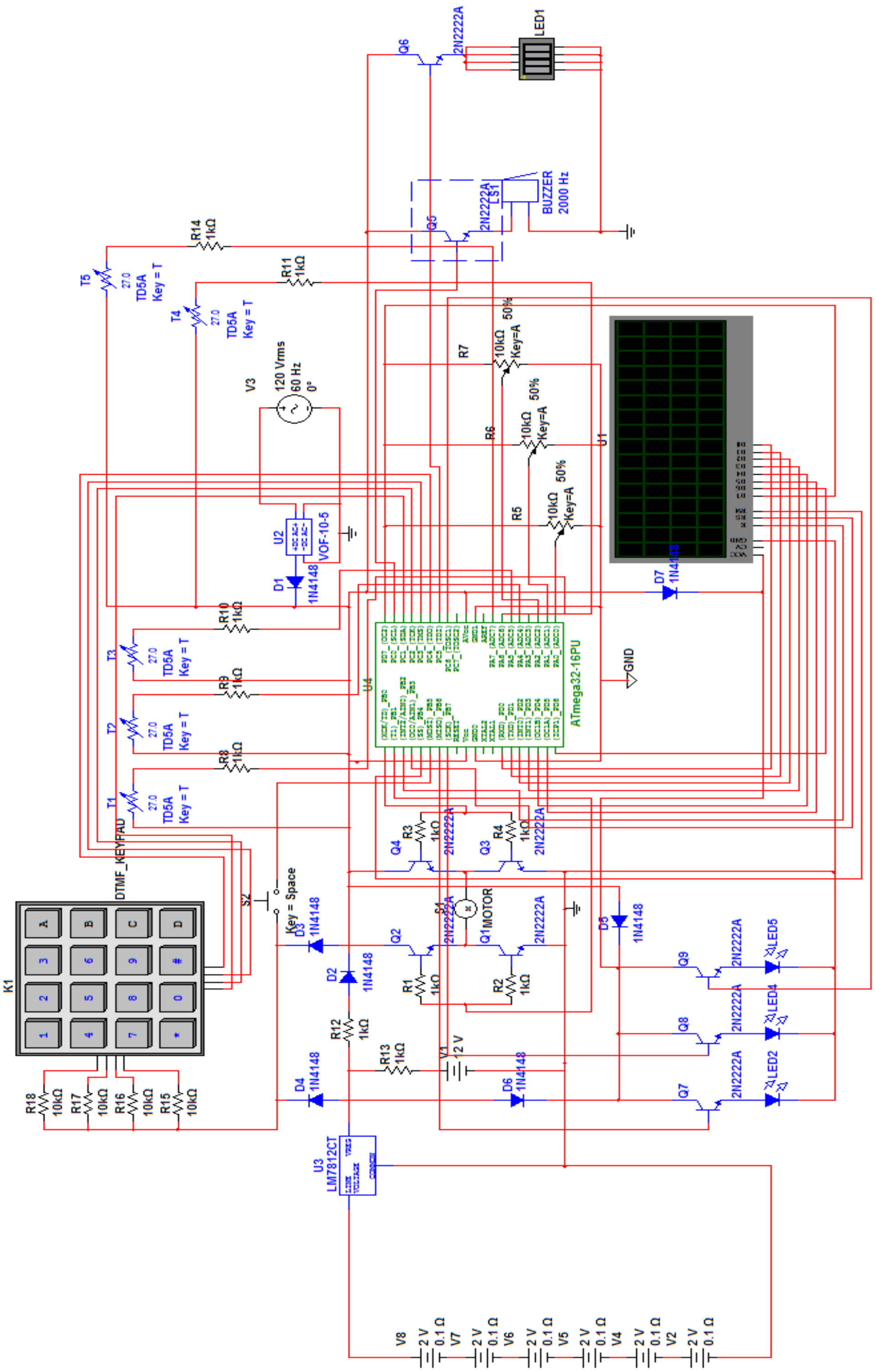


Figure 6: Circuit Diagram for Overall System

5.0: Conclusions

This project still has some untied ends in terms of the implementation; however, everything is explained and laid-out in a finalized design that somebody taking on this project as a continuation would be able to pick-up from where this project left off. In this project an overall design was achieved and a small amount of the functionality was implemented. Future work could include completely implementing the design so it is fully functional as well as optimizing for a better processor and actually interfacing the device with the stove. Overall this project was very informative and interesting to work on, especially since it was a multidisciplinary project and dealt with very real issues. In the end, all the partners on this project agreed that this design is the best fitting to the requirements for the REBCE. If this product was going to be marketed some implementation still remains, however once done the design should be appealing to a decent size market.

Works Cited

[1] Pokharel, Shankar, Ankur Sharma, Aditya Chouhan, and Dinesh Dangol. "Batho Chulho." *302 Found*. Shishir Bashyal, 2006. Web. 02 May 2012. <http://www.archive.org/stream/BathoChulho/bathochulho_djvu.tx>

Appendix A

```
/* MQP: REBCE
Advisor: Robert Labonte
Nick Knight
*/

#include <msp430x44x.h>
#include <stdlib.h>
#include <string.h>         // for some string functions

//********************************************* GLOBAL VARIABLES************************************************************
char *LCD = LCDMEM;          // pointer to LCD Memory Segments. Pretty cool, got this idea from TI-website
unsigned int timer;
unsigned int timer_length;
char disable_interrupt;
char disabled; //not in ISR, but helpful for debug

//********************************************* LCD CONSTANTS ************************************************************
#define     a      (0x80)    // definitions for LCD seegments on the Olimex LCD. 4-Mux operation is assumed
#define     b      (0x40)    // For more details on 4-Mux operation, gather your LCD datasheet,
#define     c      (0x20)    // TI's MSP430F449 User Guide (look for LCD Controller, then 4-Mux),
#define     d      (0x01)    // and MSP-449STK-2 schematic. You will need ALL these 3 when defining
#define     e      (0x02)    // each number or character. Remember, the Olimex LCD doesn't use a LCD driver!
#define     f      (0x08)    // You tell the LCD what characters to display. It's very time consuming!!
#define     g      (0x04)
#define     h      (0x10)

// ****************************************** FUNCTION DECLARATIONS ***************************************************
//void shortDelay(unsigned int max_cnt);
void init_sys(void);
void disable_timer(void);
void enable_timer(void);
void runtimerb(void);
void stoptimerb(void);
void setupADC(void);
unsigned int pollADC0(void);
unsigned int pollADC1(void);
void setupMotor(void);
void motorOnCW(void);
void motorOnCCW(void);
void motorOff(void);
void clearLCD(void);
void initLCD(void);
void shortDelay(int dSpeed);
void writeLetter(int position,char letter);
void writeWord(const char *word, int repeat_times);
void writeNumber(int long number);
void writeSentence(const char *word, int scrollForever);
```

```
//--------------------------MAIN----------------------------//
int main(){
  init_sys();

  motorOnCW();
  motorOff();
  motorOnCCW();
  motorOff();

//  float voltage = 0;
//  float Vtherm = 0;
//  unsigned int i = pollADC0();
//  unsigned int j = pollADC1();
//  voltage = (0.000734*i)-0.005872;
//  Vtherm = (0.000235*j)-0.008214;
//
//  while((voltage > 0.00 && voltage < 1.2) == 1){    //for low temperature setting
//    unsigned int i = pollADC0();
//    unsigned int j = pollADC1();
//    voltage = (0.000734*i)-0.005872;
//    Vtherm = (0.000235*j)-0.008214;
//
//    Vtherm = 1.0;
//
//    if(Vtherm < 1.2 && Vtherm > 0.00)
//      writeSentence("LOW TEMPERATURE READY",0);
//    else if(Vtherm > 1.71)
//      motorOnCW();                        //turn motor on closing the flue if temperature is above low
//    else
//      motorOnCCW();                       //else turn motor in opposite direction opening the flue
//  }
//
//  while((voltage > 1.00 && voltage < 2.2) == 1){    //for medium temperature setting
//    unsigned int i = pollADC0();
//    unsigned int j = pollADC1();
//    voltage = (0.000734*i)-0.005872;
//    Vtherm = (0.000235*j)-0.008214;
//
//    Vtherm = 2.0;
//
//    if(Vtherm > 1.00 && Vtherm > 2.2)
//      writeSentence("MEDIUM TEMPERATURE READY",0);
//    else if(Vtherm > 1.78)
//      motorOnCW();                        //turn motor on closing the flue if temperature is above medium
//    else
//      motorOnCCW();                       //else turn motor in opposite direction opening the flue
//  }
```

```
//  while((voltage > 2.00 && voltage < 3.2) == 1){    //for high temperature setting
//    //unsigned int i = pollADC0();
//    unsigned int j = pollADC1();
//    voltage = (0.000734*i)-0.005872;
//    Vtherm = (0.000235*j)-0.008214;
//
//    Vtherm = 3.0;
//
//    if(Vtherm < 3.2 && Vtherm > 2.00)
//      writeSentence("HIGH TEMPERATURE READY",0);
//    else if(Vtherm > 1.85)
//      motorOnCW();                          //turn motor on closing the flue if temperature is above high
//    else
//      motorOnCCW();                         //else turn motor in opposite direction opening the flue
//  }


//    unsigned int i = 0;
//    P1DIR |= 0x08;              // Set P1.3 to output direction to run LED
//    for (i = 1; i<=2;i++) {  // repeats words two times
//    writeWord("SYSTEM ",1);  // show this word once
//    writeWord("READY. ",1);}  // show this word once also
//    writeSentence("MSP430F449 REPORTING FOR DUTY!", 0);

}

/******************** initSys() ****************************/
void init_sys(void){
  //setup globals
  timer = 0;
  timer_length = 12000 - 1; //max legal value--will be set when timer is activated
  initLCD();                  // Setup LCD for work
  clearLCD();                 // Clear LCD display
  setupADC();                 // Setup ADC for use
  setupMotor();               // Setup motor for use
  WDTCTL = WDTPW + WDTHOLD;   // Stop watchdog timer
  _BIS_SR(GIE); // Global Interrupt enable
}

/***************Timer Functions*********************/

/* This function configures and starts Timer B */
void runtimerb(void)
{
  TBCTL = TBSSEL_1 + CNTL_0 + MC_1 + ID_0; // ACLK, 16 Bit, up mode, div=1
  TBCCR0 = 0x0147; // 327 ACLK tics = ~1/100 seconds
  TBCCTL0 = CCIE; // TBCCR0 interrupt enabled
```

```
}

/* This function stops Timer B */
void stoptimerb(void)//(int reset)
{
  TBCTL = MC_0; // stop timer
  TBCCTL0 &= ~CCIE; // TBCCR0 interrupt disabled
  /*
  if(reset)
  {
    timer=0;
    min=0;
    tsec=0;
  }
  */
}

/***************** setupADC() ***********************/
void setupADC(void){
  ADC12CTL0 &= ~ENC;
  ADC12CTL1 &= ~ENC;
  P6SEL = 0x03;                                   // Enable A/D channel A0 and A1
  ADC12CTL0 = SHT0_2 + REFON + ADC12ON + REF2_5V;  // Turn on ADC12, set sampling time, REFERENCE VOLTAGE (set to 2.5V)
  ADC12CTL1 = SHP;                                // Use sampling timer
  __delay_cycles(128);
  ADC12CTL0 |= ENC;                               // Enable conversions
  ADC12CTL1 |= ENC;
}

/***************** pollADC0() ************************/
unsigned int pollADC0(void){
  ADC12CTL0 |= ADC12SC;                 // Start conversion
  while ((ADC12IFG & BIT0)==0)
    _NOP();                             // SET BREAKPOINT HERE
  return ADC12MEM0;
}

/***************** pollADC1() ************************/
unsigned int pollADC1(void){
  ADC12CTL1 |= ADC12SC;                 // Start conversion
  while ((ADC12IFG & BIT1)!=0)
    _NOP();                             // SET BREAKPOINT HERE
  return ADC12MEM1;
}

/************************setupMotor************************/
void setupMotor(void){
```

```
  P1DIR |= 0xC0;
  P2DIR |= 0x30;
  P2SEL = 0x00;
  P1SEL = 0x00;
  motorOff();
}

/************************motorOnCW*************************/
void motorOnCW(void){
  P1OUT |= 0xC0;
}

/**********************motorOnCCW**************************/
void motorOnCCW(void){
  P2OUT |= 0x30;
}

/**********************motorOff()*************************/
void motorOff(void){
  P1OUT = 0x00;
  P2OUT = 0x00;
}

// ************************************************ numberScroll ******************************************************
void writeNumber(int long number)   // A cool function that moves number right to left
{
   unsigned int i;                      // dummy variable
   unsigned int digit;                  // dummy digit
   char Letter;

   clearLCD();

   for (i=1; i<=9; i++)                 // Extract each digit in number, put in an integer array, and count total length also
   {
      digit = number%10;                // digit = the least significant character obtained from number for display
      number = number/10;               // remove the least significant character from number

      switch(digit)                     // pass on the right char value to writeLetter function
      {
          case 0:  Letter = '0'; writeLetter(i,Letter); break;
          case 1:  Letter = '1'; writeLetter(i,Letter); break;
          case 2:  Letter = '2'; writeLetter(i,Letter); break;
          case 3:  Letter = '3'; writeLetter(i,Letter); break;
          case 4:  Letter = '4'; writeLetter(i,Letter); break;
          case 5:  Letter = '5'; writeLetter(i,Letter); break;
          case 6:  Letter = '6'; writeLetter(i,Letter); break;
          case 7:  Letter = '7'; writeLetter(i,Letter); break;
```

```
          case 8:  Letter = '8'; writeLetter(i,Letter); break;
          case 9:  Letter = '9'; writeLetter(i,Letter); break;
      }

      if (number == 0)                  // when the number has finally been reduced to zero
          break;                        // break so that LCD doesn't diplay leading zeroes. E.g 234 instead of 0000234
   }
   shortDelay(2);                       // remove this delay if you update numbers regularly
}
// ************************************************ shortDelay ****************************************************
void shortDelay(int dSpeed)  // a very easy to code delay which keeps the processor busy for a small duration of time
{
     unsigned int iDelay = 0;
     unsigned int kDelay = 0;
     for (kDelay = 1;kDelay < dSpeed * 5 ;kDelay++)   // kDelay value can be changed from 10 - 50
     {
       iDelay = 8000;                       // Do not make iDelay more than 40000. Change kDelay instead
       do (iDelay--);
       while (iDelay != 0);
     }
}

// ************************************************ initLCD *******************************************************
void initLCD(void)   // initialize the various registers for LCD to work (code obtained from sample demos of MSP430F449)
{
    FLL_CTL0 = XCAP18PF;                 //set load capacitance for 32k xtal
    // Initialize LCD driver (4Mux mode)
    LCDCTL = LCDSG0_7 + LCD4MUX + LCDON; // 4mux LCD, segs16-23 = outputs
    BTCTL  = BT_fLCD_DIV128;             // set LCD frame freq = ACLK
    P5SEL  = 0xFC;                       // set Rxx and COM pins for LCD
}

// ************************************************ clearLCD ******************************************************
void clearLCD(void) // makes the LCD blank
{   // clear LCD memory to clear display
    unsigned int iLCD;
    for (iLCD =0; iLCD<20; iLCD++)  // clears all 20 LCD memory segments
    {
      LCD[iLCD] = 0;
    }
}

// ***********************************************  writeLetter ***************************************************
void writeLetter(int position,char letter) // writes a single character on the LCD. User can specify position as well
{
    // DO NOT PLAY WITH THE CODE BELOW ---------------------------------------------------------------------------
    if (position == 1)  {  position = position + 6; } // this is position adjustment for compatibility.
```

```
else if (position == 2 || position == 3 || position == 4 || position == 5 || position == 6 || position == 7)
{  position = ((position * 2) - 1) + 6; }  // adjust position
// ------------------------------------------------------------------------------------------------------------

switch(letter)
{
   // letter  // LCDM7                            // LCDM8                          // End
   case 'A':  LCD[position-1] = a + b + c + e;      LCD[position] = b + c + g;         break;
   case 'B':  LCD[position-1] = c + h + e;          LCD[position] = b + c + g;         break;
   case 'C':  LCD[position-1] = a + h;              LCD[position] = b + c;             break;
   case 'D':  LCD[position-1] = b + c + h + e;      LCD[position] = c + g;             break;
   case 'E':  LCD[position-1] = a + h + e;          LCD[position] = b + c + g;         break;
   case 'F':  LCD[position-1] = a;                  LCD[position] = b + c + g;         break;
   case 'G':  LCD[position-1] = a + c + h + e;      LCD[position] = b + c;             break;
   case 'H':  LCD[position-1] = b + c + e;          LCD[position] = b + c + g;         break;
   case 'I':  LCD[position-1] = a + h + f;          LCD[position] = d;                 break;
   case 'J':  LCD[position-1] = b + h + c;          LCD[position] = c;                 break;
   case 'K':  LCD[position-1] = d + g;              LCD[position] = b + c + g;         break;
   case 'L':  LCD[position-1] = h;                  LCD[position] = b + c ;            break;
   case 'M':  LCD[position-1] = b + c + g;          LCD[position] = b + c + f;         break;
   case 'N':  LCD[position-1] = b + c + d;          LCD[position] = b + c + f;         break;
   case 'O':  LCD[position-1] = a + b + c + h;      LCD[position] = b + c;             break;
   case 'P':  LCD[position-1] = a + b + e;          LCD[position] = b + c + g;         break;
   case 'Q':  LCD[position-1] = a + b + c + h + d;  LCD[position] = b + c;             break;
   case 'R':  LCD[position-1] = a + b + d + e;      LCD[position] = b + c + g;         break;
   case 'S':  LCD[position-1] = a + c + h + e;      LCD[position] = b + g;             break;
   case 'T':  LCD[position-1] = a + f + b;          LCD[position] = d + b;             break;
   case 'U':  LCD[position-1] = b + c + h;          LCD[position] = b + c;             break;
   case 'V':  LCD[position-1] = g;                  LCD[position] = b + c + e;         break;
   case 'W':  LCD[position-1] = b + c + d;          LCD[position] = b + c + e;         break;
   case 'X':  LCD[position-1] = d + g;              LCD[position] = e + f;             break;
   case 'Y':  LCD[position-1] = b + c + h + e;      LCD[position] = f;                 break;
   case 'Z':  LCD[position-1] = a + h + g;          LCD[position] = e;                 break;

   // number  // LCDM7                              // LCDM8                          // END
   case '0':  LCD[position-1] = a + b + c + h;      LCD[position] = b + c;             break;
   case '1':  LCD[position-1] = b + c;                                                 break;
   case '2':  LCD[position-1] = a + b + e + h;      LCD[position] = c + g;             break;
   case '3':  LCD[position-1] = a + b + c + e + h;  LCD[position] = g;                 break;
   case '4':  LCD[position-1] = b + c + e;          LCD[position] = b + g;             break;
   case '5':  LCD[position-1] = a + c + h + e;      LCD[position] = b + g;             break;
   case '6':  LCD[position-1] = a + c + h + e;      LCD[position] = b + c + g;         break;
   case '7':  LCD[position-1] = a + b + c;                                             break;
   case '8':  LCD[position-1] = a + b + c + e + h;  LCD[position] = b + c + g;         break;
   case '9':  LCD[position-1] =a + b + c + e ;      LCD[position] = b + g;             break;

   // others
```
s

```
        case '^':                               LCDM2 = c;              break;  // top arrow
        case '!':                               LCDM2 = a;              break;  // bottom arrow
        case '>':                               LCDM2 = b;              break;  // right arrow
        case '<':                               LCDM2 = h;              break;  // left arrow
        case '+':                               LCDM20= a;              break;  // plus sign
        case '-':                               LCDM20= h;              break;  // minus sign
        case '&':                               LCDM2 = d;              break;  // zero battery
        case '*':                               LCDM2 = d + f;          break;  // low battery
        case '(':                               LCDM2 = d + f + g;      break;  // medium battery
        case ')':                               LCDM2 = d + e + f + g;  break;  // full battery */
    }
}

// ***********************************************  writeSentence*************************************************************

void writeSentence(const char *word, int scrollForever)  // writes out an entire sentence scrolling it right to left
                                                           // sentences must be in upper case
{
   unsigned int strLength = 0;          // variable to store length of the sentence
   unsigned int i;                      // dummy variable
   unsigned int j;                      // dummy variable
   unsigned int k;                      // dummy variable
   char letter_list[75];               // keeps track of characters. Sentence can have upto 74 characters. Do not make too large
   unsigned int position_list[75];     // keeps track of position of the characters
   unsigned int marker = 0;             // keeps track of index of the last being displayed character
   unsigned int dispCount = 0;          // keep count of how many characters are being displayed
   unsigned int flag = 1;               // a normal flag that defines if process should be stopped

   strLength = strlen(word);            // get the length of the sentence

   for (i = 1; i <= strLength; i++)     // put each character in string in a special array called letter_list
   {
      letter_list[strLength - i + 1] = word[i-1];
      position_list[i] = 0;             // also, place their relative position values in an array called position_list
   }

   marker = strLength;                  // marker takes the position of the last character
   position_list[marker] = 1;           // Set the marker of this position to 1
   dispCount++;                         // dispCount = 1; meaning we start display with 1 character

   do                                   // Digit Shifter with light + delay
   {
      shortDelay(2);                    // take a short break so that the user can see the changes
      clearLCD();                       // since we are gonna update LCD soon, clear the LCD first
      P1OUT ^= 0x08;                    // toggle the pin connected to LED to that we can see it blinking

      for (k = marker; k >= marker - dispCount + 1; k--)   // display the first frame
```

```
        {
            writeLetter(position_list[k],letter_list[k]);
        }

        if (dispCount < 7)                  // update frame count (characters to be displayed during next frame)
          { dispCount++; }

        for (i = marker; i >= marker - dispCount + 1;i--) // shift the relative position values
        {
            position_list[i] = position_list[i] + 1;
            if (position_list[i] == 8)
            {   marker--;                               // shift the marker value

               if (marker - dispCount + 1 <= 0)
               {
                  marker = dispCount;                   // make sure marker never goes less than zero
               }

            }
        }

        if (position_list[1] == 2)                      // when marker has hit maximum index
           {
                 if (scrollForever == 0)
                 {  flag = 0; clearLCD();  }            // adjust flag value to repeat or not
                 marker = strLength;                    // reset marker to original
                 dispCount = 1;                         // display length of frame to 1
                 for (j = 1; j <= 50; j++)              // reset position_list to original
                 {
                    if (marker != j)
                    { position_list[j] = 0; }
                    else if (marker == j)
                    { position_list[j] = 1; }           // set position list of marker character to 1
                 }
            }
     } while (flag == 1);                               // function repeats forever if flag remains 1

}

// **********************************************  writeSentence***********************************************************
void writeWord(const char *word, int repeat_times)  // displays a word (upto 7 characters) for specified number of times
                                                    // words must be in upper case
{
   unsigned int strLength = 0;   // variable to store length of word
   unsigned int i;               // dummy variable
   unsigned int k;               // dummy variable
```

```
   strLength = strlen(word);      // get the length of word now

   for (k = 1; k <= repeat_times; k++)  // repeat display
   {
       for (i = 1; i <= strLength; i++) // display word
       {
          writeLetter(strLength - i + 1,word[i-1]);  // displays each letter in the word
       }
       shortDelay(3);         // software delay
       clearLCD();            // clears the LCD
       shortDelay(3);         // software delay
   }

}

// ************************* short Tutorial on using LCD commands effectively ******************************************

/* //(a) To display battery life indicator (copy and paste the following):
         writeLetter(1,'&');   // zero battery life
         shortDelay(5);

         writeLetter(1,'*');  // low
         shortDelay(5);

         writeLetter(1,'(');  // medium
         shortDelay(5);

         writeLetter(1,')');  // full battery life
         shortDelay(5);                              */
    // ------------------------------------------------------------------


/*  //(b) To display + and - signs:
          writeLetter(1,'+');   // displays plus sign
          shortDelay(5);
          writeLetter(1,'-');   // displays negative sign  */
    // ------------------------------------------------------------------

/*  //(c) To display signed numbers with decimals:
          writeWord("+153.89",1);       */
    //  -----------------------------------------------------------------

/*  //(d) To display a number excluding decimals
          writeNumber(1234567);   */
    // ------------------------------------------------------------------

/*  //(e) To display a number including decimals
     // ------------------------------------------------------------------

/*   //(g)To display the arrows on LCD:
          writeLetter(1,'^');    // shows top arrow
          shortDelay(5);

          writeLetter(1,'!');    // shows bottom arrow
          shortDelay(5);

          writeLetter(1,'>');    // shows right arrow
          shortDelay(5);

          writeLetter(1,'<');    // shows left arrow
          shortDelay(5);       */
```

Appendix B

Features

- High-performance, Low-power AVR® 8-bit Microcontroller
- RISC Architecture
  - 130 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
  - 8K Bytes of In-System Self-programmable Flash
    Endurance: 10,000 Write/Erase Cycles
  - Optional Boot Code Section with Independent Lock bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - 512 Bytes EEPROM
    Endurance: 100,000 Write/Erase Cycles
  - 512 Bytes Internal SRAM
  - Up to 64K Bytes Optional External Memory Space
  - Programming Lock for Software Security
- Peripheral Features
  - One 8-bit Timer/Counter with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Three PWM Channels
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Three Sleep Modes: Idle, Power-down and Standby
- I/O and Packages
  - 35 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, 44-lead PLCC, and 44-pad QFN/MLF
- Operating Voltages
  - 2.7 - 5.5V for ATmega8515L
  - 4.5 - 5.5V for ATmega8515
- Speed Grades
  - 0 - 8 MHz for ATmega8515L
  - 0 - 16 MHz for ATmega8515

8-bit AVR® Microcontroller with 8K Bytes In-System Programmable Flash

ATmega8515 ATmega8515L

2512K–AVR–01/10

U.S. SENSOR Corp.
Thermistors, RTDs, Probes & Assemblies
1-800-777-6467

Thin Film Platinum RTD's

U.S. Sensor
1832 W. Collins Ave
Orange, CA 92867
Tel: 800-777-6467
Tel: 714-639-1000
Fax: 714-639-1220
Email: sales@ussensor.com

U.S. Sensor's thin film platinum resistance temperature detectors (Pt-RTD) consist of a thin film platinum deposited on a ceramic substrate. Thin film Pt-RTD's provide cost advantages when compared to wire wound Pt-RTD's because of their lower material cost factor.

Features

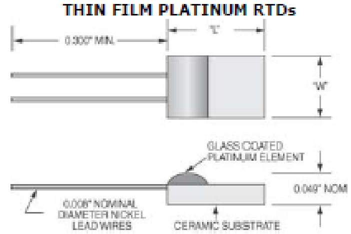
Download Page

- Glass coated platinum element
- Virtually linear relationship between temperature and resistance
- Capable of withstanding temperatures ranging from -50°C to +500°C. Higher temperature ratings are available by special order
- High accuracy: Resistance and temperature deviation can be controlled to within ±0.06% and ±0.15°C, a tolerance that corresponds to Class "A" of IEC 751 or 1/2 DIN of DIN 43760
- High Reliability: Capable of withstanding extreme environmental conditions
- Available in various probe configurations for specific applications
- Excellent stability even at high temperatures

Specifications

- Thermal time constant: 15 seconds max. (moving air)
- Dissipation constant: 2mW/°C (moving air)
- Maximum applied current: 1 mA

THIN FILM PLATINUM RTDs



View Photo

RTD THIN PLATINUM

Part Number	Resistance Ohms @ 0°C	DIN 43760 Class	Resistance Tol ±% @ 0°C	Temp. Dev. ±°C @ 0°C	TCR ppm/°C	Dim "W" (±0.007)	Dim "L" (±0.008)	View R-T Chart
PPG101A1	100	A	0.06	0.15	3850	0.067	0.110	
PPG101B1	100	B	0.12	0.30	3850	0.067	0.110	
PPG101C1	100	C	0.24	0.60	3850	0.067	0.110	
PPG501A1	500	A	0.06	0.15	3850	0.079	0.118	
PPG501B1	500	B	0.12	0.30	3850	0.079	0.118	
PPG501C1	500	C	0.24	0.60	3850	0.079	0.118	
PPG102A1	1000	A	0.06	0.15	3850	0.079	0.118	
PPG102B1	1000	B	0.12	0.30	3850	0.079	0.118	
PPG102C1	1000	C	0.24	0.60	3850	0.079	0.118	
PPG102B2	1000	B	0.12	0.30	3750	0.079	0.118	
PPG102C2	1000	C	0.24	0.60	3750	0.079	0.118	

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TECHNICAL DATA MQ-7 GAS SENSOR

FEATURES

* High sensitivity to carbon monoxide
* Stable and long life

APPLICATION

They are used in gas detecting equipment for carbon monoxide(CO) in family and industry or car.

SPECIFICATIONS

A. Standard work condition

Symbol	Parameter name	technical condition	Remark
Vc	circuit voltage	5V±0.1	Ac or Dc
V_H (H)	Heating voltage (high)	5V±0.1	Ac or Dc
V_H (L)	Heating voltage (low)	1.4V±0.1	Ac or Dc
R_L	Load resistance	Can adjust	
R_H	Heating resistance	33Ω±5%	Room temperature
$T_{H(H)}$	Heating time (high)	60±1 seconds	
$T_{H(L)}$	Heating time (low)	90±1 seconds	
PH	Heating consumption	Less than 330mw	

b. Environment conditions

Symbol	Parameters	Technical conditions	Remark
Tao	Using temperature	-20℃-50℃	
Tas	Storage temperature	-20℃-50℃	Advice using scope
RH	Relative humidity	Less than 95%RH	
O_2	Oxygen concentration	21%(stand condition) the oxygen concentration can affect the sensitivity characteristic	Minimum value is over 2%

c. Sensitivity characteristic

symbol	Parameters	Technical parameters	Remark
Rs	Surface resistance Of sensitive body	2-20k	In 100ppm Carbon Monoxide
a (300/100ppm)	Concentration slope rate	Less than 0.5	Rs (300ppm)/Rs(100ppm)
Standard working condition	Temperature -20℃±2℃ relative humidity 65%±5% RL:10KΩ±5%		
	Vc:5V±0.1V VH:5V±0.1V VH:1.4V±0.1V		
Preheat time	No less than 48 hours	Detecting range: 20ppm-2000ppm carbon monoxide	

D. Structure and configuration, basic measuring circuit

Structure and configuration of MQ-7 gas sensor is shown as Fig. 1(Configuration A or B), sensor composed by micro AL_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-7 have

TECHNICAL DATA MQ-135 GAS SENSOR

FEATURES

Wide detecting scope Fast response and High sensitivity
Stable and long life Simple drive circuit

APPLICATION

They are used in air quality control equipments for buildings/offices, are suitable for detecting of NH3,NOx, alcohol, Benzene, smoke,CO_2 ,etc.

SPECIFICATIONS

A. Standard work condition

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
V_H	Heating voltage	5V±0.1	ACOR DC
R_L	Load resistance	can adjust	
R_H	Heater resistance	33Ω±5%	Room Tem
P_H	Heating consumption	less than 800mw	

B. Environment condition

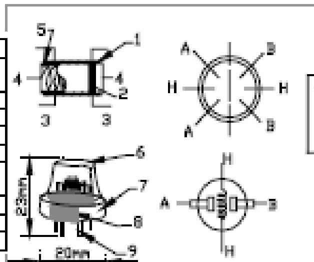
Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10□-45□	
Tas	Storage Tem	-20□-70□	
R_H	Related humidity	less than 95%Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	minimum value is over 2%

C. Sensitivity characteristic

Symbol	Parameter name	Technical parameter	Ramark 2
Rs	Sensing Resistance	30KΩ-200KΩ (100ppm NH_3)	Detecting concentration scope: 10ppm-300ppm NH_3 10ppm-1000ppm Benzene 10ppm-300ppm Alcohol
α (200/50) NH_3	Concentration Slope rate	≤0.65	
Standard Detecting Condition	Temp: 20□±2□ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1		
Preheat time	Over 24 hour		

D. Structure and configuration, basic measuring circuit

	Parts	Materials
1	Gas sensing layer	SnO_2
2	Electrode	Au
3	Electrode line	Pt
4	Heater coil	Ni-Cr alloy
5	Tubular ceramic	Al_2O_3
6	Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7	Clamp ring	Copper plating Ni
8	Resin base	Bakelite
9	Tube Pin	Copper plating Ni



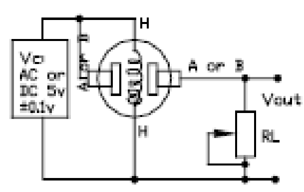
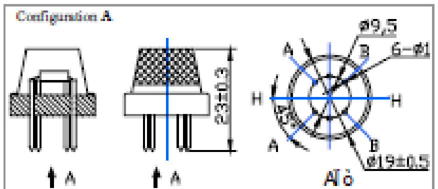
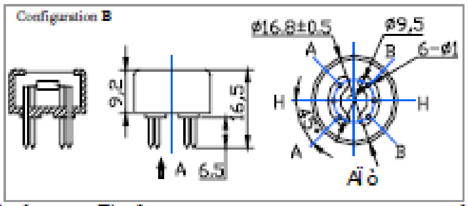


Fig.2

Fig. 1





Structure and configuration of MQ-135 gas sensor is shown as Fig. 1 (**Configuration A or B**), sensor composed by micro AL_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-135 have 6 pin ,4 of them are used to fetch signals, and other 2 are used for providing heating current.

Electric parameter measurement circuit is shown as Fig.2

E. Sensitivity characteristic curve

Fig.2 sensitivity characteristics of the MQ-135

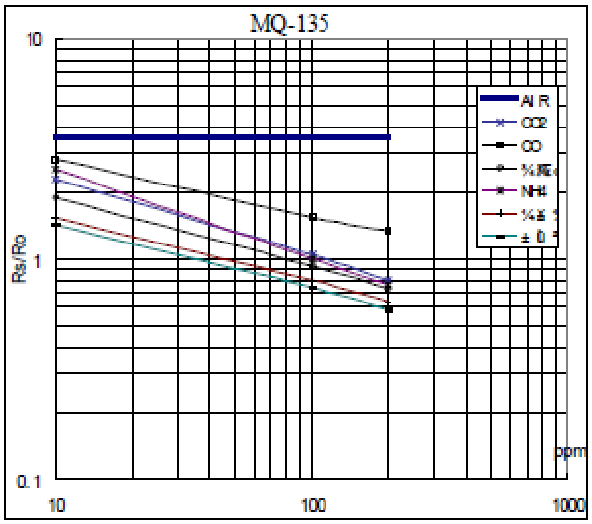


Fig.3 is shows the typical sensitivity characteristics of the MQ-135 for several gases.
in their: Temp: 20℃
Humidity: 65%
O_2 concentration 21%
RL=20kΩ
Ro: sensor resistance at 100ppm of NH_3 in the clean air.
Rs:sensor resistance at various concentrations of gases.

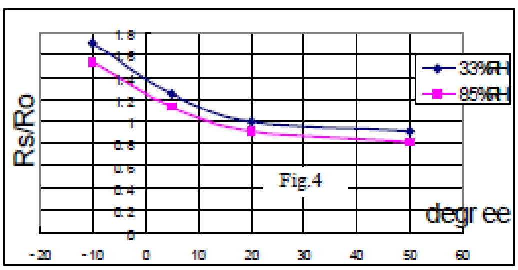
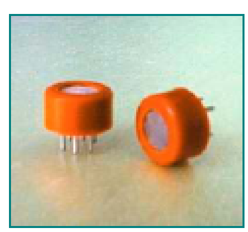


Fig.4 is shows the typical dependence of the MQ-135 on temperature and humidity.
Ro: sensor resistance at 100ppm of NH_3 in air at 33%RH and 20 degree.
Rs: sensor resistance at 100ppm of NH_3 at different temperatures and humidities.

SENSITVITY ADJUSTMENT

Resistance value of MQ-135 is difference to various kinds and various concentration gases. So,When using this components, sensitivity adjustment is very necessary. we recommend that you calibrate the detector for 100ppm NH_3 or 50ppm Alcohol concentration in air and use value of Load resistancethat(R_L) about 20 KΩ(10KΩ to 47 KΩ).

When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.



Kingbright

T-1 3/4(5mm) SOLID STATE LAMPS

L53HD BRIGHT RED	L53Gx GREEN
L53Ix HIGH EFFICIENCY RED	L53Yx YELLOW
L53EC HIGH EFFICIENCY RED	L53ED ORANGE
L53Nx PURE ORANGE	L53PGx PURE GREEN

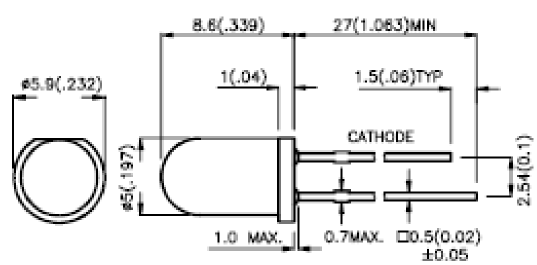
Features

- HIGH INTENSITY.
- LOW POWER CONSUMPTION.
- POPULAR T-1 3/4 DIAMETER PACKAGE.
- GENERAL PURPOSE LEADS.
- RELIABLE AND RUGGED.
- LONG LIFE-SOLID STATE RELIABILITY.
- AVAILABLE ON TAPE AND REEL.

Description

The Bright Red source color devices are made with Gallium Phosphide Red Light Emitting Diode.
The Green source color devices are made with Gallium Phosphide Green Light Emitting Diode.
The High Efficiency Red and Orange source color devices are made with Gallium Arsenide Phosphide on Gallium Phosphide Orange Light Emitting Diode.
The Yellow source color devices are made with Gallium Arsenide Phosphide on Gallium Phosphide Yellow Light Emitting Diode.
The Pure Orange source color devices are made with Gallium Arsenide Phosphide on Gallium Phosphide Pure Orange Light Emitting Diode.
The Pure Green source color devices are made with Gallium Phosphide Pure Green Light Emitting Diode.

Package Dimensions



Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the lead emerge package.
4. Specifications are subject to change without notice.

SPEC NO: CDA0704 REV NO: V.1 DATE: NOV/12/2001 PAGE: 1 OF 7
APPROVED : J. Lu CHECKED: DRAWN: Z.W.Yan

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Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) @ 10 mA Min.	Iv (mcd) @ 10 mA Typ.	Viewing Angle 2θ1/2
L53HD	BRIGHT RED (GaP)	RED DIFFUSED	2	5	60°
L53ID	HIGH EFFICIENCY RED (GaAsP/GaP)	RED DIFFUSED	8	25	60°
L53IT		RED TRANSPARENT	30	80	30°
L53EC		WATER CLEAR	30	80	30°
L53ED	ORANGE (GaAsP/GaP)	ORANGE DIFFUSED	8	30	60°
L53GD	GREEN (GaP)	GREEN DIFFUSED	5	20	60°
L53GT		GREEN TRANSPARENT	20	60	30°
L53GC		WATER CLEAR	20	60	30°
L53YD	YELLOW (GaAsP/GaP)	YELLOW DIFFUSED	5	20	60°
L53YT		YELLOW TRANSPARENT	20	40	30°
L53YC		WATER CLEAR	20	40	30°
L53ND	PURE ORANGE (GaAsP/GaP)	ORANGE DIFFUSED	12	30	60°
L53NT		ORANGE TRANSPARENT	50	80	30°
L53NC		WATER CLEAR	50	80	30°
L53PGD	PURE GREEN (GaP)	GREEN DIFFUSED	2	5	60°
L53PGT		GREEN TRANSPARENT	5	10	30°
L53PGC		WATER CLEAR	5	10	30°

Note:
1. θ1/2 is the angle from optical centerline where the luminous intensity is 1/2 the optical centerline value.

Absolute Maximum Ratings at T_A=25°C

Parameter	Bright Red	High Efficiency Red	Orange	Green	Yellow	Pure Orange	Pure Green	Units
Power dissipation	120	105	105	105	105	105	105	mW
DC Forward Current	25	30	30	25	30	30	25	mA
Peak Forward Current [1]	120	160	160	140	140	145	135	mA
Reverse Voltage	5	5	5	5	5	5	5	V
Operating/Storage Temperature	-40°C To +85°C							
Lead Soldering Temperature [2]	260°C For 5 Seconds							

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 4mm below package base.

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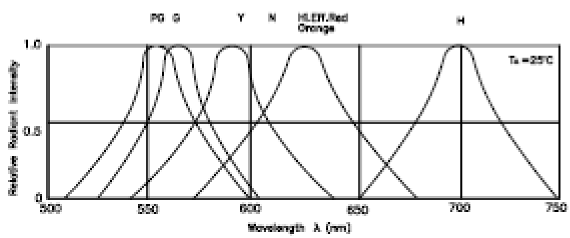
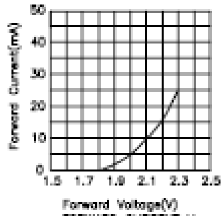
Electrical / Optical Characteristics at T_A=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Bright Red High Efficiency Red Orange Green Yellow Pure Orange Pure Green	700 627 627 565 590 607 555		nm	IF=20mA
λ D	Dominate Wavelength	Bright Red High Efficiency Red Orange Green Yellow Pure Orange Pure Green	660 625 625 568 588 610 555		nm	IF=20mA
Δλ1/2	Spectral Line Halfwidth	Bright Red High Efficiency Red Orange Green Yellow Pure Orange Pure Green	45 45 45 30 35 35 30		nm	IF=20mA
C	Capacitance	Bright Red High Efficiency Red Orange Green Yellow Pure Orange Pure Green	40 15 15 15 20 15 45		pF	VF=0V;f=1MHz
V_F	Forward Voltage	Bright Red High Efficiency Red Orange Green Yellow Pure Orange Pure Green	2.25 2.0 2.0 2.0 2.1 2.05 2.25	2.5 2.5 2.5 2.5 2.5 2.5 2.5	V	IF=20mA
I_R	Reverse Current	All		10	uA	VR = 5V

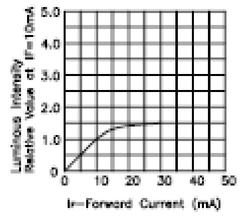


RELATIVE INTENSITY Vs. WAVELENGTH

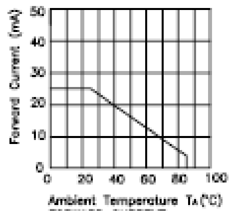
Bright Red L53HD



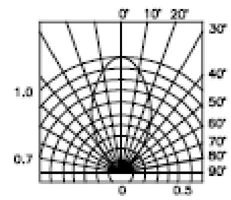
FORWARD CURRENT Vs.
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT

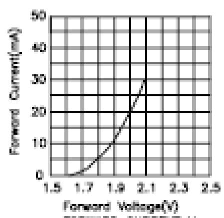


FORWARD CURRENT
DERATING CURVE

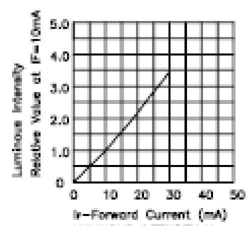


SPATIAL DISTRIBUTION

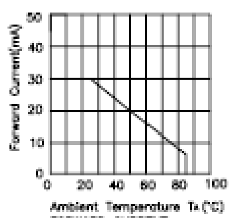
High Efficiency Red L53ID,L53IT



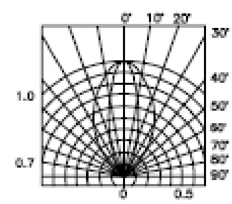
FORWARD CURRENT Vs
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT



FORWARD CURRENT
DERATING CURVE



SPATIAL DISTRIBUTION

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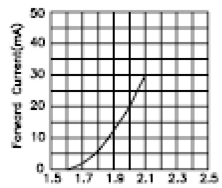
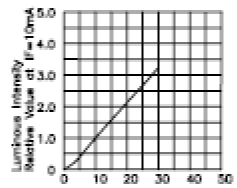
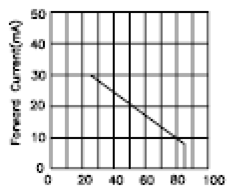
High Efficiency Red L53EC
Orange L53ED



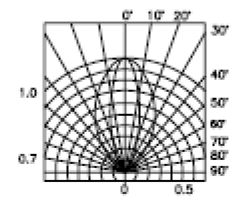
FORWARD CURRENT Vs
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT

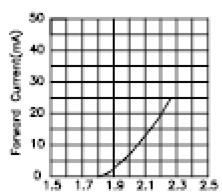


FORWARD CURRENT
DERATING CURVE

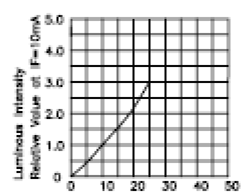


SPATIAL DISTRIBUTION

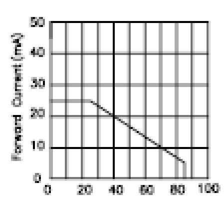
Green L53GD,L53GC,L53GT



FORWARD CURRENT Vs
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT



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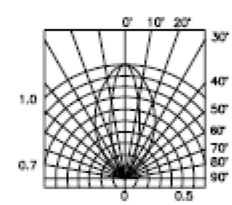

SPATIAL DISTRIBUTION

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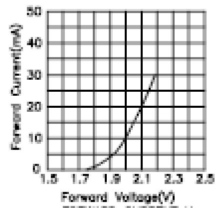
Yellow L53YD,L53YC,L53YT



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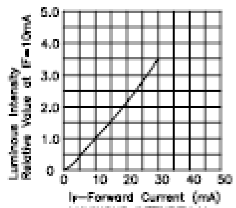
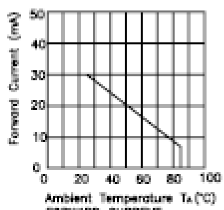
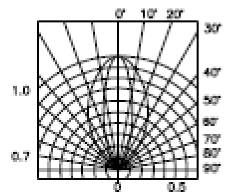
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT

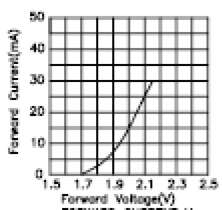


FORWARD CURRENT
DERATING CURVE

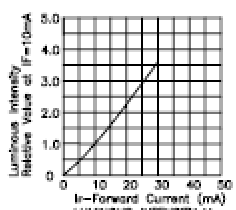


SPATIAL DISTRIBUTION

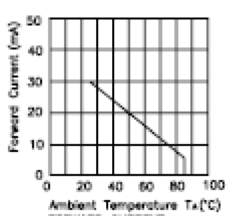
Pure Orange L53ND,L53NC,L53NT



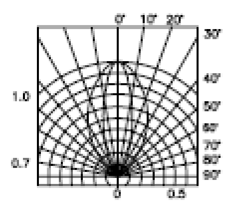
FORWARD CURRENT Vs.
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT

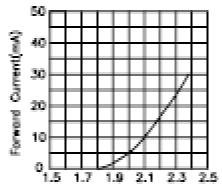


FORWARD CURRENT
DERATING CURVE

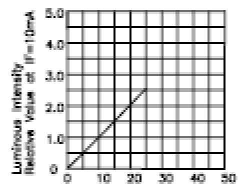


SPATIAL DISTRIBUTION

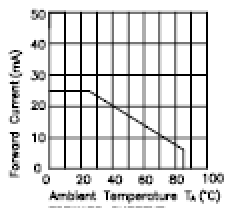
Pure Green L53PGD,L53PGC,L53PGT



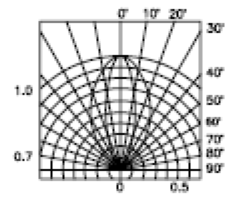
FORWARD CURRENT Vs
FORWARD VOLTAGE



LUMINOUS INTENSITY Vs.
FORWARD CURRENT



FORWARD CURRENT
DERATING CURVE



SPATIAL DISTRIBUTION

Kingbright

T-1 3/4 (5mm) SOLID STATE LAMP

Part Number: WP7113CGCK Green

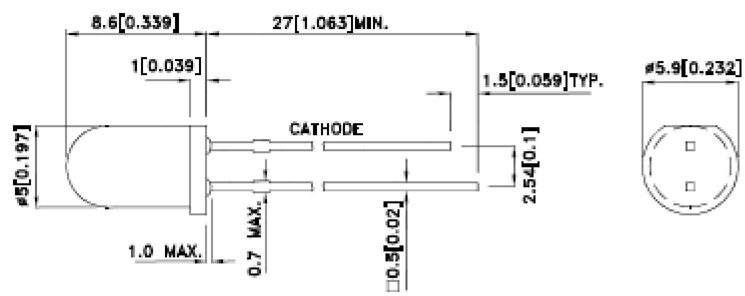
Features

- Low power consumption.
- Popular T-1 3/4 diameter package.
- General purpose leads.
- Reliable and rugged.
- Long life - solid state reliability.
- Available on tape and reel.
- RoHS compliant.

Description

The Green source color devices are made with AlGaInP on GaAs substrate Light Emitting Diode.

Package Dimensions



Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the leads emerge from the package.
4. The specifications, characteristics and technical data described in the datasheet are subject to change without prior notice.

Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) [2] @ 20mA		Viewing Angle [1]
			Min.	Typ.	$2\theta 1/2$
WP7113CGCK	Green (AlGaInP)	Water Clear	400	700	20°

Notes:
1. $\theta 1/2$ is the angle from optical centerline where the luminous intensity is 1/2 of the optical peak value.
2. Luminous intensity/ luminous Flux: +/-15%.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Green	574		nm	I_F=20mA
λD [1]	Dominant Wavelength	Green	570		nm	I_F=20mA
Δλ1/2	Spectral Line Half-width	Green	20		nm	I_F=20mA
C	Capacitance	Green	15		pF	V_F=0V;f=1MHz
V_F [2]	Forward Voltage	Green	2.1	2.5	V	I_F=20mA
I_R	Reverse Current	Green		10	uA	V_R = 5V

Notes:
1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

Parameter	Green	Units
Power dissipation	75	mW
DC Forward Current	30	mA
Peak Forward Current [1]	150	mA
Reverse Voltage	5	V
Operating/Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 3 Seconds	
Lead Solder Temperature [3]	260°C For 5 Seconds	

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.
3. 5mm below package base.

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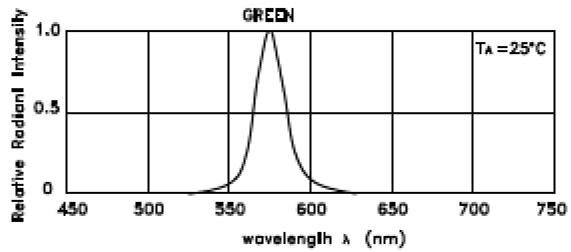
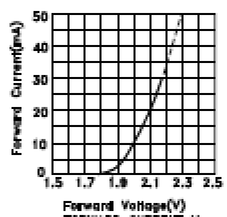
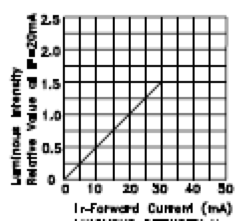


RELATIVE INTENSITY Vs. WAVELENGTH

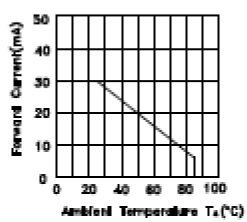
Green WP7113CGCK



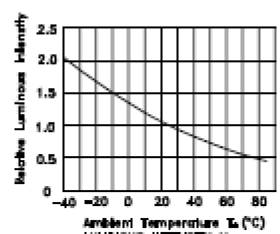
FORWARD CURRENT Vs.
FORWARD VOLTAGE



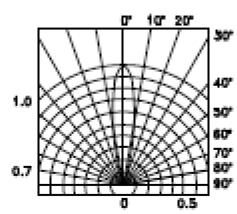
LUMINOUS INTENSITY Vs.
FORWARD CURRENT



FORWARD CURRENT
DERATING CURVE



LUMINOUS INTENSITY Vs.
AMBIENT TEMPERATURE



SPATIAL DISTRIBUTION

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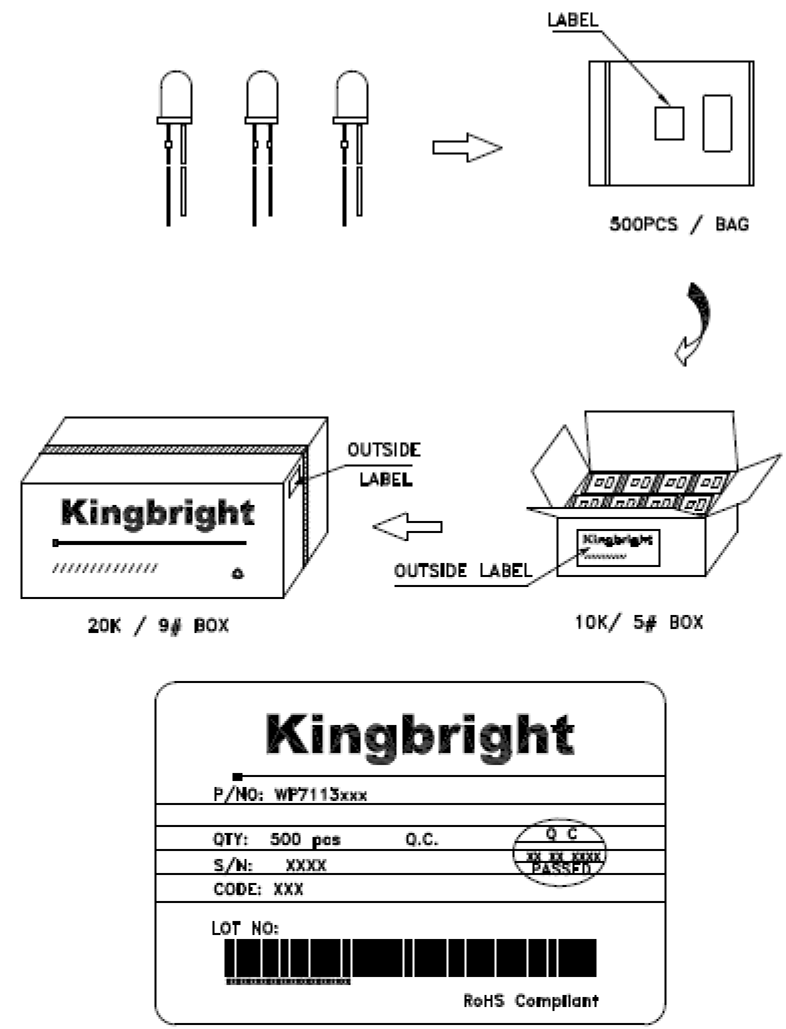
PACKING & LABEL SPECIFICATIONS WP7113CGCK



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PRECAUTIONS

1. The lead pitch of the LED must match the pitch of the mounting holes on the PCB during component placement. Lead–forming may be required to insure the lead pitch matches the hole pitch. Refer to the figure below for proper lead forming procedures. (Fig. 1)

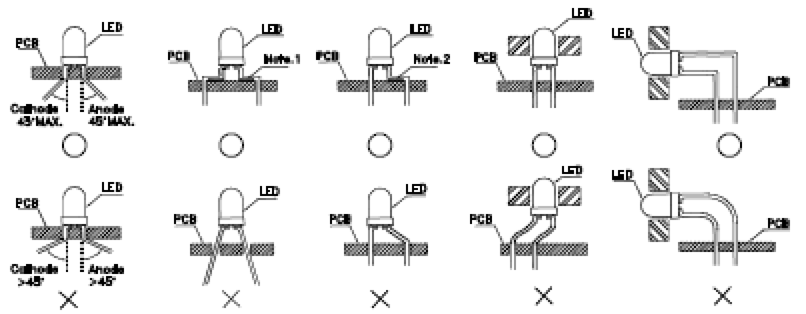


Fig.1

"○" Correct mounting method "×" Incorrect mounting method

2. When soldering wire to the LED, use individual heat–shrink tubing to insulate the exposed leads to prevent accidental contact short–circuit. (Fig.2)

3. Use stand–offs (Fig.3) or spacers (Fig.4) to securely position the LED above the PCB.

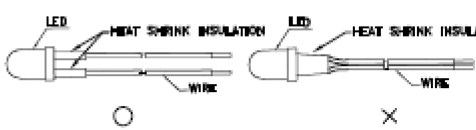


Fig. 2

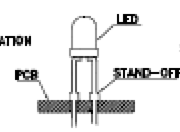


Fig. 3

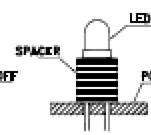


Fig. 4

4. Maintain a minimum of 2mm clearance between the base of the LED lens and the first lead bend. (Fig. 5 and 6)
5. During lead forming, use tools or jigs to hold the leads securely so that the bending force will not be transmitted to the LED lens and its internal structures. Do not perform lead forming once the component has been mounted onto the PCB. (Fig. 7)

Kingbright

6. Do not bend the leads more than twice. (Fig. 8)

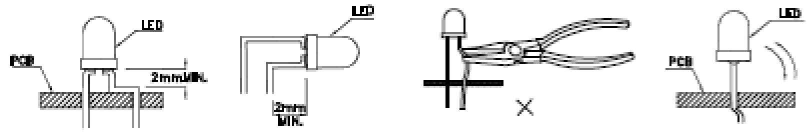
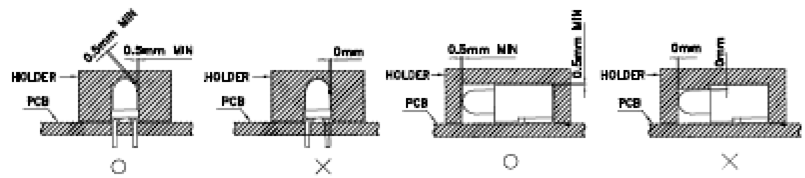
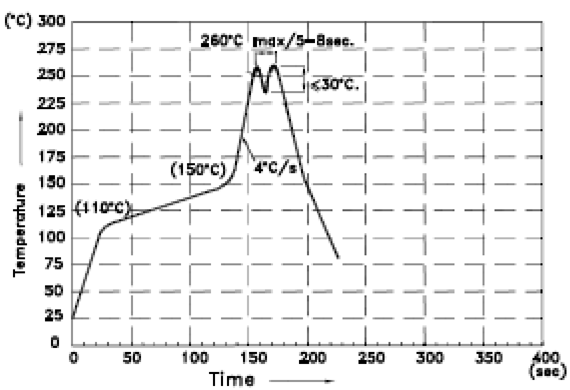


Fig. 5 Fig. 6 Fig. 7 Fig. 8

7. During soldering, component covers and holders should leave clearance to avoid placing damaging stress on the LED during soldering.



8. The tip of the soldering iron should never touch the lens epoxy.
9. Through-hole LEDs are incompatible with reflow soldering.
10. If the LED will undergo multiple soldering passes or face other processes where the part may be subjected to intense heat, please check with Kingbright for compatibility.
11. Recommended Wave Soldering Profile for Kingbright Thru-Hole Products



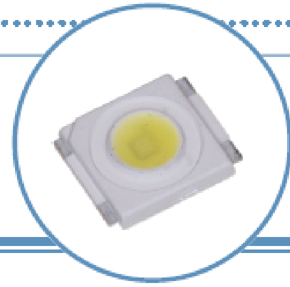
NOTES:
1.Recommend the wave temperature 245°C~260°C.The maximum soldering temperature should be less than 260°C.
2.Do not apply stress on epoxy resins when temperature is over 85°C.
3.The soldering profile apply to the lead free soldering (Sn/Cu/Ag alloy).
4.During wave soldering, the PCB top-surface temperature should be kept below 105°C.
5.No more than once.

1-Watt SMD 6mm (120° Viewing Angle)

TT electronics
OPTEK Technology

OVSPW1BCR4

- Robust energy-efficient design with long operating life
- Low thermal resistance—10 C/W
- Exceptional spatial uniformity
- Optional optics to suit application
- High Lumens output

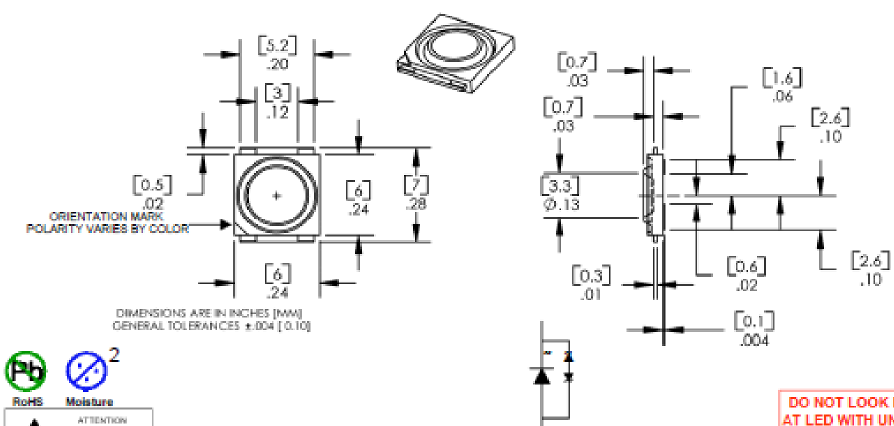


The **OVSPW1BCR4** is an energy-efficient packaged LED source that offers high luminance, and a long operating lifespan. This device offers a 120° viewing angle and an ultra-low profile (1.5mm) making it highly suitable for conventional lighting and specialized applications. Optional optics are offered to suit application. Please contact OPTEK for more information.

Applications

- Automotive exterior and interior lighting
- Architectural indoor and outdoor lighting
- General lighting
- Electronic signs and signals

Part Number	Viewing Angle	Emitted Color	Typical Luminous Flux (lm)	Typical On-Axis Intensity (cd)	Lens Color
OVSPW1BCR4	120 °	White	90	na	Water Clear



RoHS Moisture 2

ATTENTION
OBSERVE PRECAUTIONS
ELECTROSTATIC
SENSITIVE DEVICES

DO NOT LOOK DIRECTLY AT LED WITH UNSHIELDED EYES OR DAMAGE TO RETINA MAY OCCUR.

OPTEK reserves the right to make changes at any time in order to improve design and to supply the best product possible.

Absolute Maximum Ratings $T_A = 25°C$

DC Forward Current	350mA
Peak Pulsed Forward Current[1]	1000mA
Reverse Voltage	Not designed for reverse bias
Junction Temperature[2]	125°C
Power Dissipation	1200mW
Storage and Operating Temperature	-40° ~ +100 ° C
ESD Threshold (HBM)	2000V

Notes:
1. Pulse width tp ≤ 10µs, Duty cycle = 0.1
2. Thermal conductivity = 10 C/W

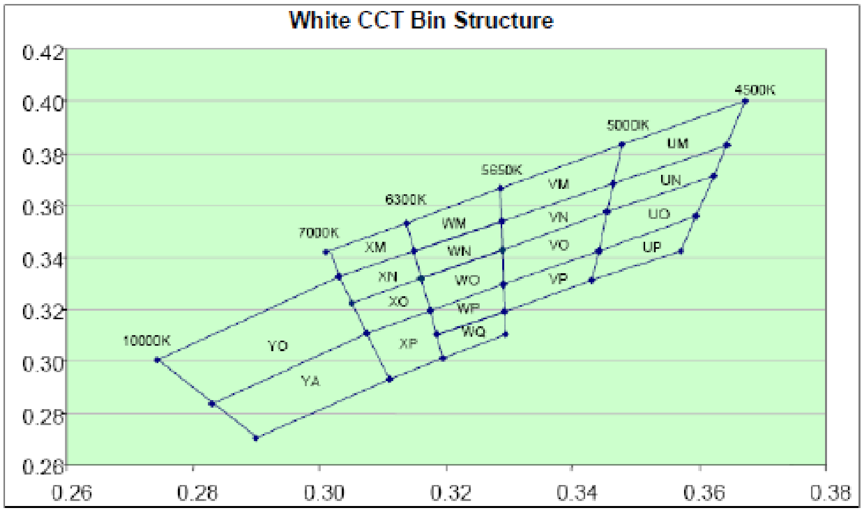
Optical and Electrical Characteristics

(I_F = 350 mA, T_A = 25° C)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
V_F	Forward Voltage	3.0	3.5	4.0	V
Φ	Luminous Flux	67	90	113	lm
I_R	Reverse Current	----	10	----	µA
2 Θ½	50% Power Angle	----	120	----	deg

Standard Bins (I_F = 350 mA) **OVSPW1BCR4 (White)**

LEDs are sorted to luminous flux (Φ), chromaticity coordinates, and correlated color temperature (CCT) bins shown. Orders may be filled with any or all bins contained as below.



Color Bin	Minimum CCT (K)	Maximum CCT (K)
U	4500	5000
V	5000	5650
W	5650	6300
X	6300	7000
Y	7000	10000

Φ	Luminous Flux (lm	
Bin	Min	Max
T2	67.2	76.5
T3	76.5	87.4
U2	87.4	99.4
U3	99.4	113.6

Bin		1	2	3	4
YO	Cx	0.274	0.303	0.308	0.283
	Cy	0.301	0.333	0.311	0.284
YA	Cx	0.283	0.308	0.311	0.290
	Cy	0.284	0.311	0.293	0.270
XM	Cx	0.301	0.314	0.315	0.303
	Cy	0.342	0.353	0.343	0.333
XN	Cx	0.303	0.315	0.316	0.305
	Cy	0.333	0.343	0.332	0.322
XO	Cx	0.305	0.316	0.318	0.308
	Cy	0.322	0.332	0.319	0.311
XP	Cx	0.308	0.318	0.320	0.311
	Cy	0.311	0.319	0.301	0.293
WM	Cx	0.314	0.329	0.329	0.315
	Cy	0.353	0.366	0.354	0.343
WN	Cx	0.315	0.329	0.329	0.316
	Cy	0.343	0.354	0.343	0.332
WO	Cx	0.316	0.329	0.329	0.318
	Cy	0.332	0.343	0.330	0.319
WP	Cx	0.318	0.329	0.329	0.319
	Cy	0.319	0.330	0.319	0.310
WQ	Cx	0.319	0.329	0.330	0.320
	Cy	0.310	0.319	0.311	0.301
VM	Cx	0.329	0.348	0.347	0.329
	Cy	0.366	0.383	0.368	0.354
VN	Cx	0.329	0.347	0.346	0.329
	Cy	0.354	0.368	0.357	0.343
VO	Cx	0.329	0.346	0.344	0.329
	Cy	0.343	0.357	0.343	0.330
VP	Cx	0.329	0.344	0.343	0.329
	Cy	0.330	0.343	0.331	0.319
UM	Cx	0.348	0.367	0.364	0.347
	Cy	0.383	0.400	0.383	0.368
UN	Cx	0.347	0.364	0.362	0.346
	Cy	0.368	0.383	0.372	0.357
UO	Cx	0.346	0.362	0.359	0.344
	Cy	0.357	0.372	0.356	0.343
UP	Cx	0.344	0.359	0.357	0.343
	Cy	0.343	0.356	0.343	0.331

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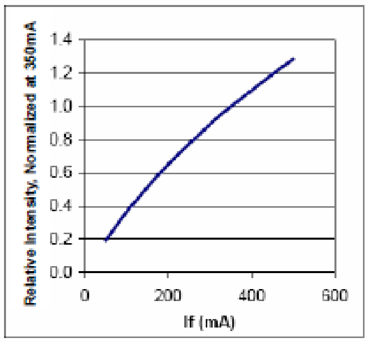
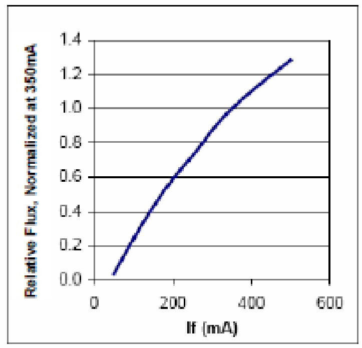
Typical Electro-Optical Characteristics Curves

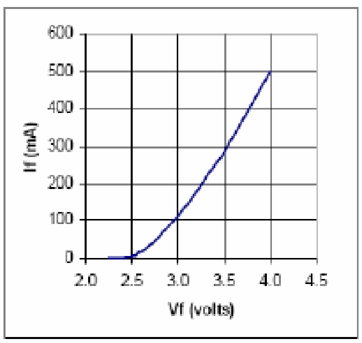
Relative luminous intensity vs. forward current.



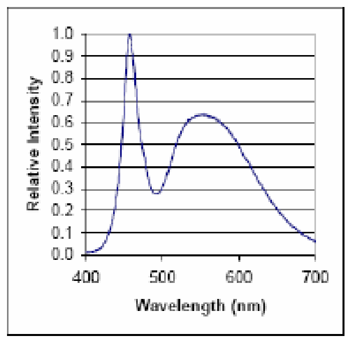
Flux vs. forward current.



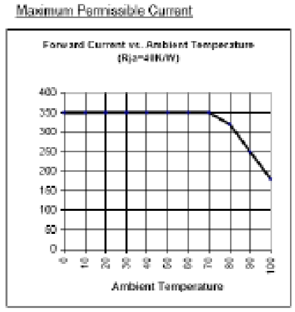
Forward current vs. forward voltage.



Relative Spectra Emission

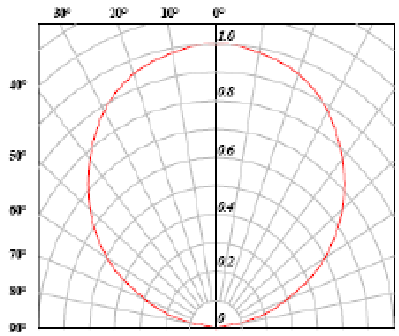


Maximum Permissible Current



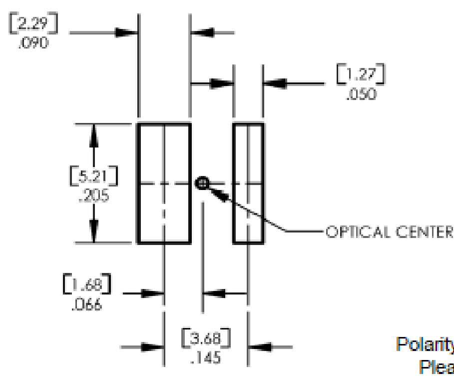
OPTEK reserves the right to make changes at any time in order to improve design and to supply the best product possible.

Radiation Pattern



Solder Pad Design

Note: Metal core circuit board (MCPCB) is highly recommended for high density applications. Please consult sales and marketing for additional information.



Polarity varies with color.
Please see Page 1.

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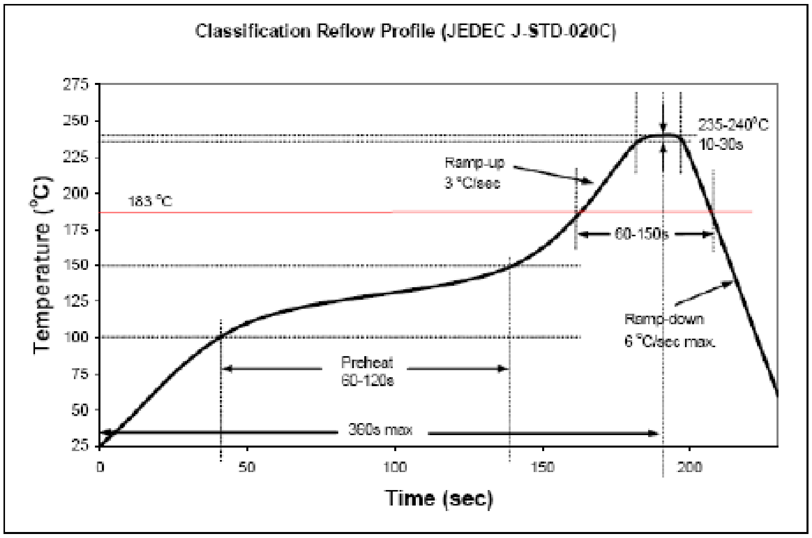
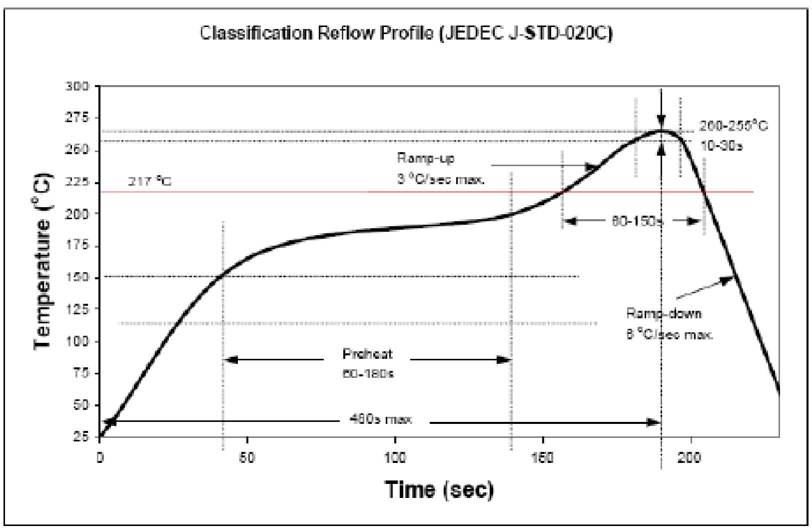
Recommended Sn-Pb IR-Reflow Soldering Profile.



Recommended Pb Free IR-Reflow Soldering Profile.



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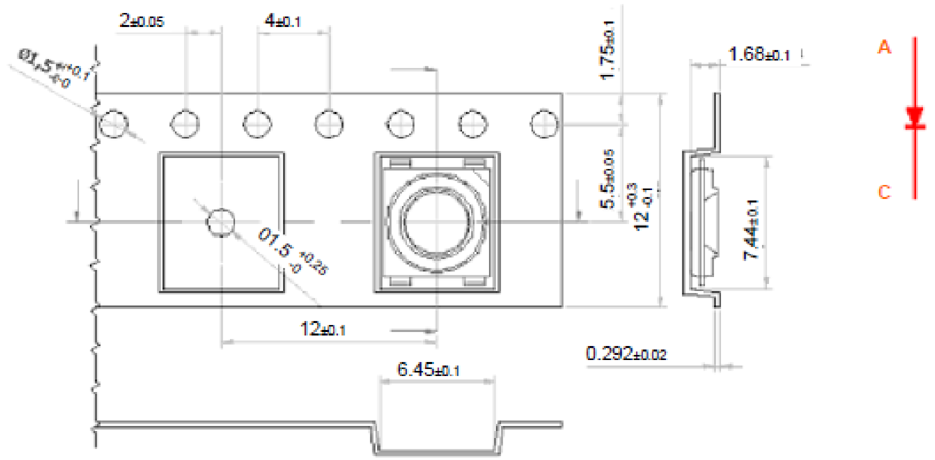
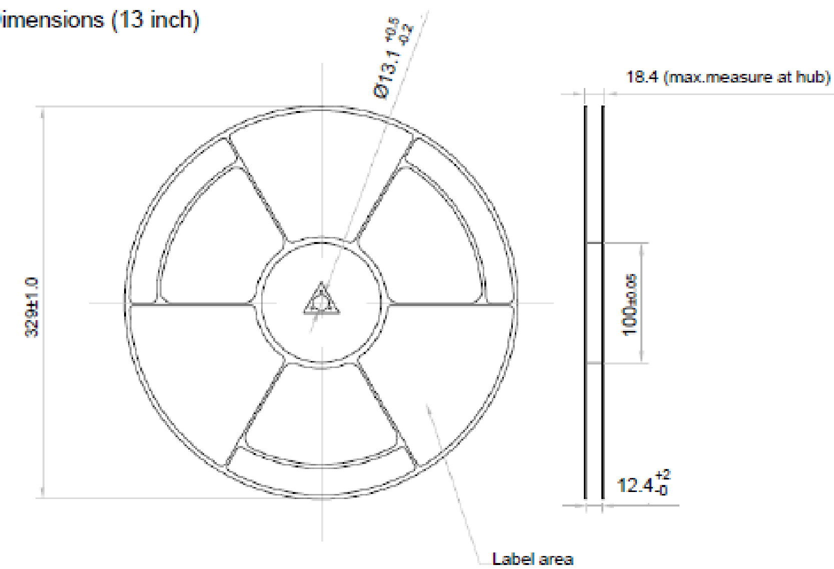
Taping and Orientation

Loaded quantity 2000 pieces per reel



Reel Dimensions (13 inch)



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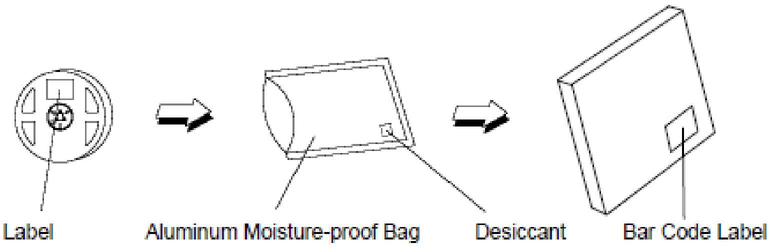
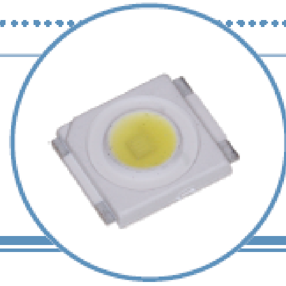
Moisture Resistant Packaging



1-Watt SMD 6mm (120° Viewing Angle)

OVSPW1BCR4

- Robust energy-efficient design with long operating life
- Low thermal resistance—10 C/W
- Exceptional spatial uniformity
- Optional optics to suit application
- High Lumens output



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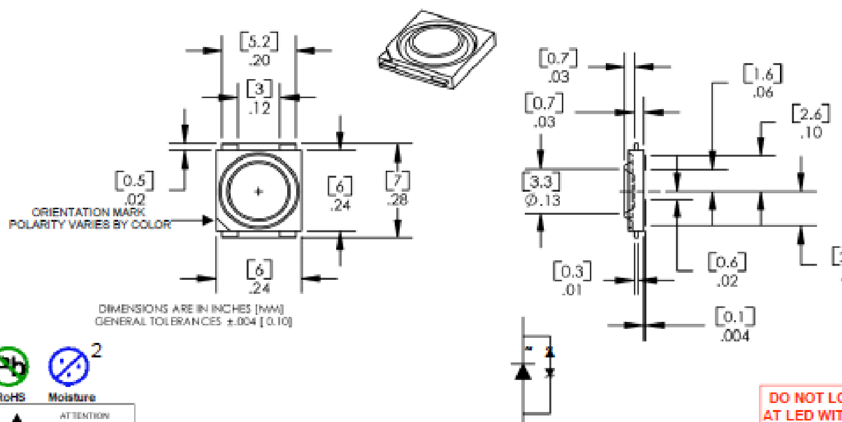

RoHS Moisture 2

ATTENTION

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Absolute Maximum Ratings $T_A = 25°C$

DC Forward Current	350mA
Peak Pulsed Forward Current[1]	1000mA
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Junction Temperature[2]	125°C
Power Dissipation	1200mW
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ESD Threshold (HBM)	2000V

Notes:
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2. Thermal conductivity = 10 C/W

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Standard Bins (I_F = 350 mA) OVSPW1BCR4 (White)

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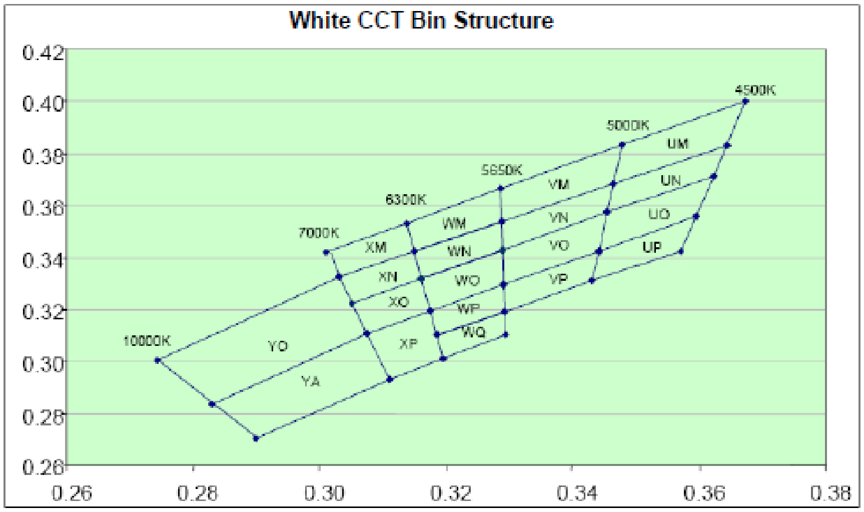

Color Bin	Minimum CCT (K)	Maximum CCT (K)
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W	5650	6300
X	6300	7000
Y	7000	10000

Φ	Luminous Flux (lm	
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	Cy	0.322	0.332	0.319	0.311
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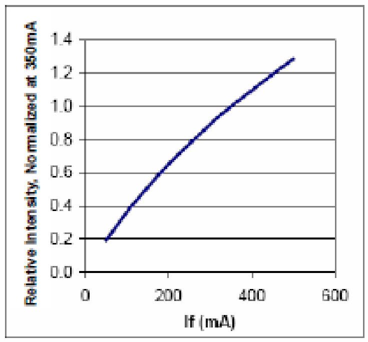
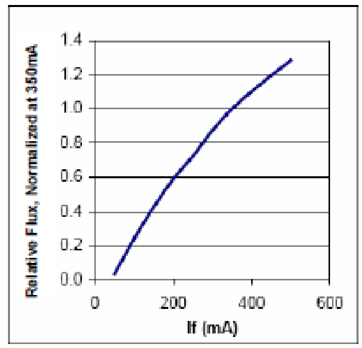
	Cy	0.311	0.319	0.301	0.293
WM	Cx	0.314	0.329	0.329	0.315
	Cy	0.353	0.366	0.354	0.343
WN	Cx	0.315	0.329	0.329	0.316
	Cy	0.343	0.354	0.343	0.332
WO	Cx	0.316	0.329	0.329	0.318
	Cy	0.332	0.343	0.330	0.319
WP	Cx	0.318	0.329	0.329	0.319
	Cy	0.319	0.330	0.319	0.310
WQ	Cx	0.319	0.329	0.330	0.320
	Cy	0.310	0.319	0.311	0.301
VM	Cx	0.329	0.348	0.347	0.329
	Cy	0.366	0.383	0.368	0.354
VN	Cx	0.329	0.347	0.346	0.329
	Cy	0.354	0.368	0.357	0.343
VO	Cx	0.329	0.346	0.344	0.329
	Cy	0.343	0.357	0.343	0.330
VP	Cx	0.329	0.344	0.343	0.329
	Cy	0.330	0.343	0.331	0.319
UM	Cx	0.348	0.367	0.364	0.347
	Cy	0.383	0.400	0.383	0.368
UN	Cx	0.347	0.364	0.362	0.346
	Cy	0.368	0.383	0.372	0.357
UO	Cx	0.346	0.362	0.359	0.344
	Cy	0.357	0.372	0.356	0.343
UP	Cx	0.344	0.359	0.357	0.343
	Cy	0.343	0.356	0.343	0.331

Typical Electro-Optical Characteristics Curves

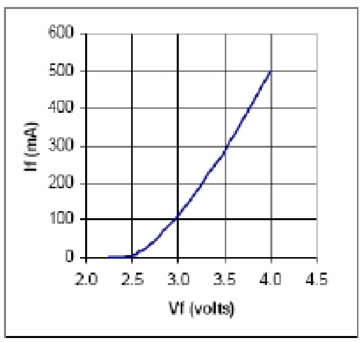
Relative luminous intensity vs. forward current.



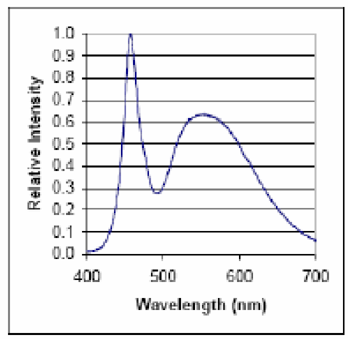
Flux vs. forward current.



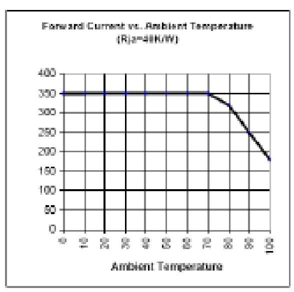
Forward current vs. forward voltage.



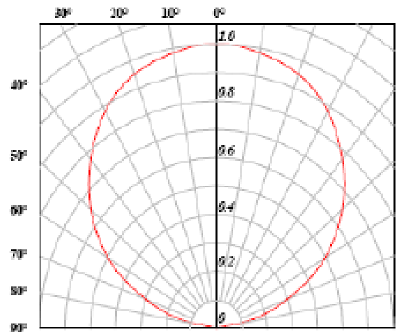
Relative Spectra Emission



Maximum Permissible Current

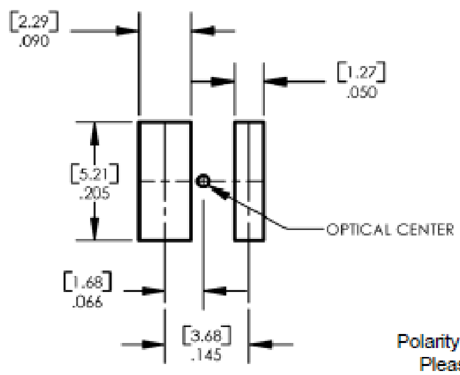


Radiation Pattern



Solder Pad Design

Note: Metal core circuit board (MCPCB) is highly recommended for high density applications. Please consult sales and marketing for additional information.



Polarity varies with color.
Please see Page 1.

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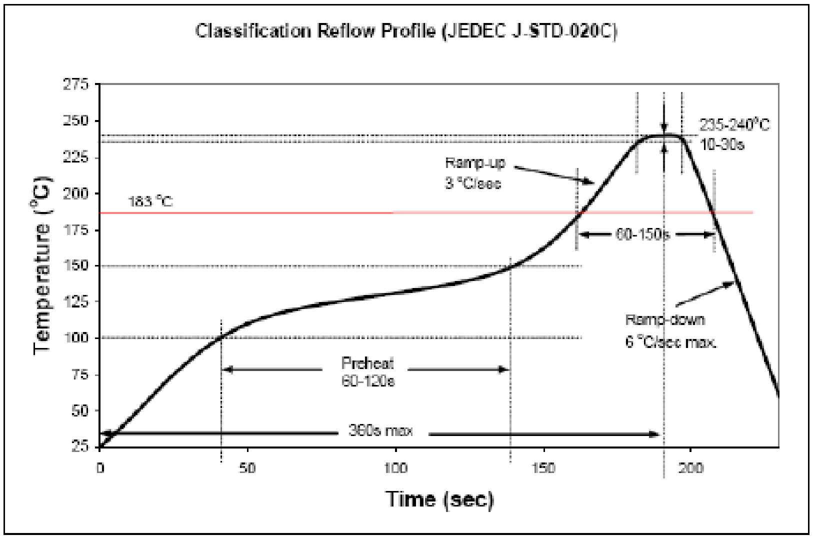
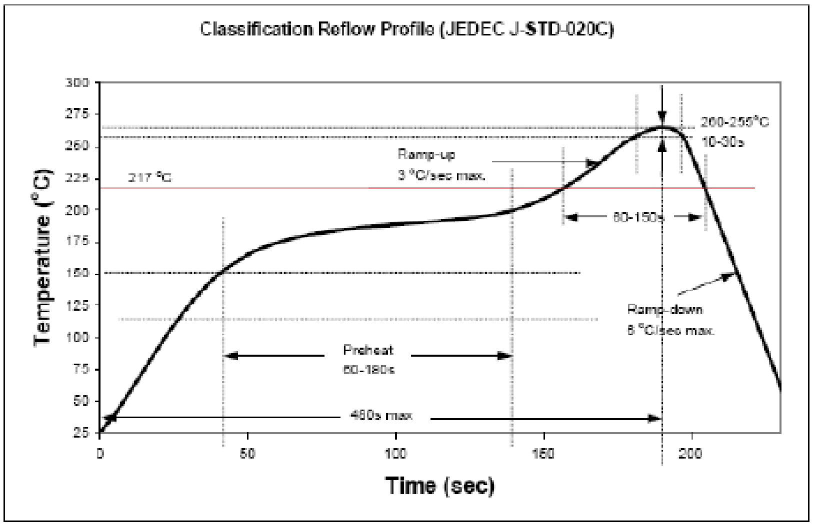
Recommended Sn-Pb IR-Reflow Soldering Profile.



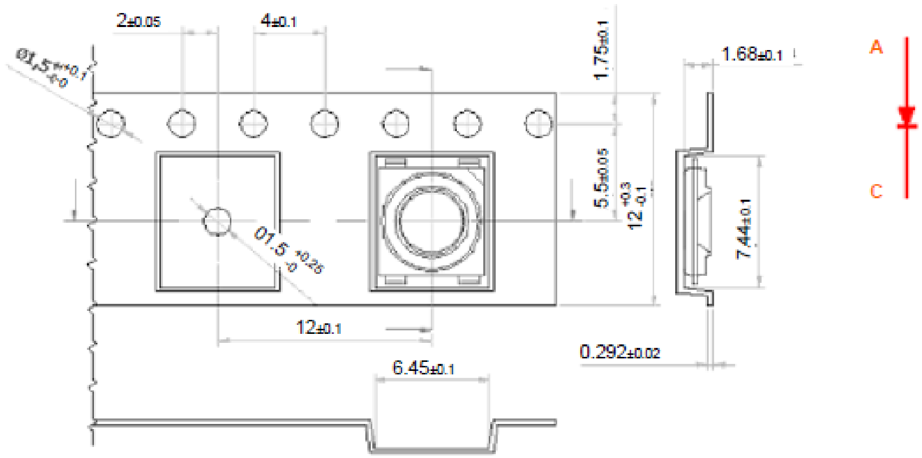
Recommended Pb Free IR-Reflow Soldering Profile.



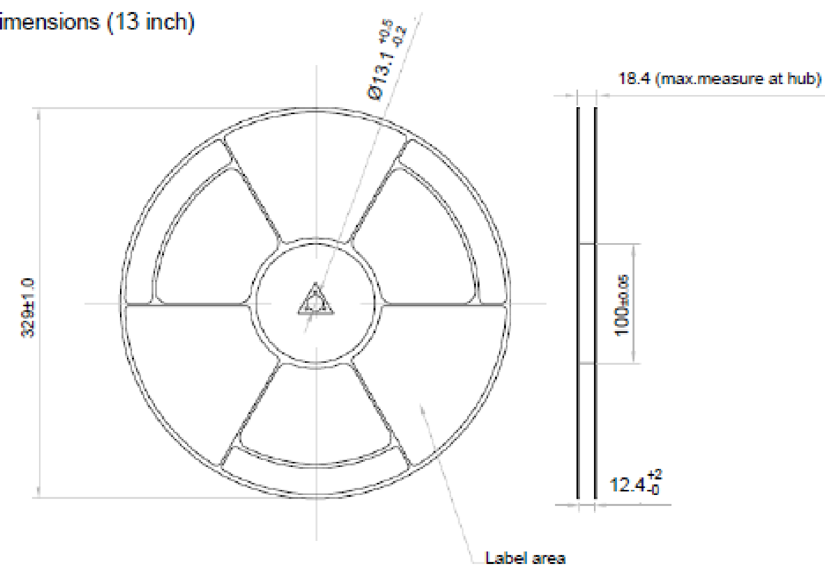
OPTEK reserves the right to make changes at any time in order to improve design and to supply the best product possible.

Taping and Orientation

Loaded quantity 2000 pieces per reel



Reel Dimensions (13 inch)



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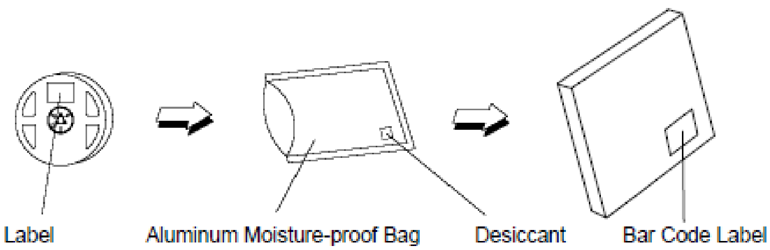
Moisture Resistant Packaging

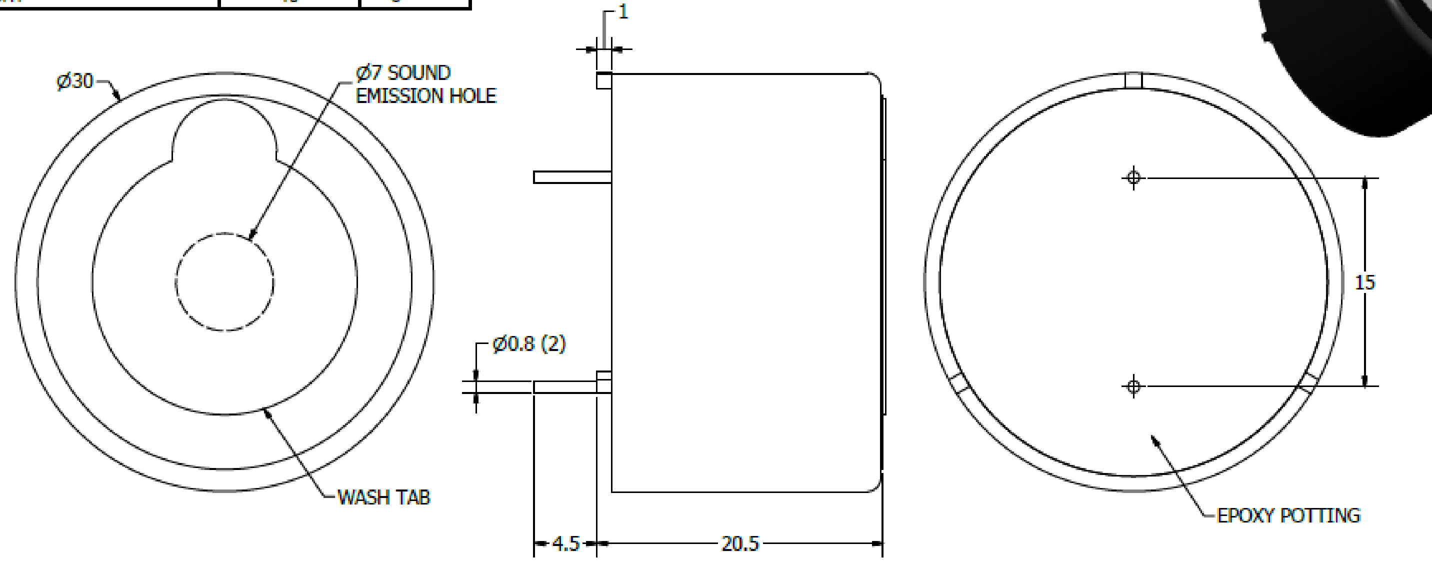


SPECIFICATIONS

PARAMETERS	VALUES	UNITS
RATED VOLTAGE	3	Vdc
OPERATING VOLTAGE RANGE	2 ~ 5	Vdc
RATED CURRENT (MAX)	9	mA
MINIMUM SPL @ 10 CM	100	dBA
RESONANT FREQUENCY	3,500 ± 500	Hz
TONE OR PULSE RATE	CONTINUOUS	0 pulse/sec
OPERATING TEMPERATURE	-20 ~ +80	°C
STORAGE TEMPERATURE	-30 ~ +85	°C
HOUSING MATERIAL	PBT	-
TERMINAL MATERIAL	Sn PLATED COPPER	-
WEIGHT	10	grams

REVISION HISTORY

LTR	DESCRIPTION	DATE	APPROVED
-	RELEASED FROM ENGINEERING	3/22/2006	
A	REVISED BODY HEIGHT DIMENSION	4/18/2008	B.R.
B	REVISED TO INVENTOR 3-D DRAWING TEMPLATE	6/14/2008	B.R.
C	REVISED HEIGHT AND STAND-OFF DIMENSIONS	9/23/2011	M.L.



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. SPECIFICATIONS SUBJECT TO CHANGE OR WITHDRAWL WITHOUT NOTICE.
3. THIS PART IS RoHS 2002/95/EC COMPLIANT.

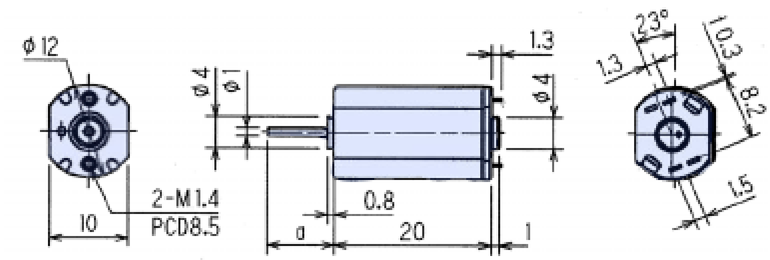
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS. TOLERANCES ARE ±0.5 AND ANGLES ARE ±3°.	SIZE A3	Designed by	Date	Checked by	Date	Approved by	Date	Drawn Date
		T.G.	3/22/2006	B.R.	3/22/2006	E.P.	3/22/2006	6/14/2008
AI-3035-TWT-3V-R.idw		pui audio inc a projects unlimited company		AI-3035-TWT-3V-R				
				Indicator			Edition -	Sheet 1 / 1

NMB-MAT
Minebea Motor Manufacturing Corporation
eMINEBEA.COM

M1N10

■ Outline UNIT:mm

Weight: 17.7 g

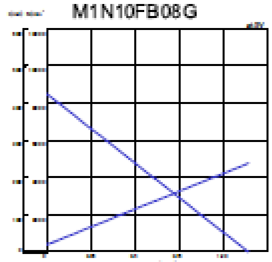


■ Specifications

Model	Operating Voltage (V)	Rated Voltage (V)	No Load Speed (min^{-1})	No Load Current (mA)	Rated Load		Rated Load Speed (min^{-1})	Rated Load Current (mA)	Starting Torque		Starting Current (mA)	Shaft Length (mm)
					(gf·cm)	(mN·m)			(gf·cm)	(mN·m)		
M1N10FB08G	1 to 6	5.0	8483	20	3.1	0.3	6258	77	11.7	1.1	238	a=8.5
M1N10FB95G	1 to 6	5.0	10277	20	3.1	0.3	8542	90	18.1	1.8	433	a=8.5
M1N10FB09F	1 to 6	5.0	10822	23	3.1	0.3	8714	96	15.7	1.5	399	a=6.5
M1N10FB10G	1 to 6	5.0	13316	36	3.1	0.3	10988	131	17.5	1.7	575	a=8.5
M1N10FB11G	1 to 6	5.0	15906	36	3.1	0.3	13850	145	23.7	2.3	874	a=8.5

■ Characteristics

M1N10FB08G



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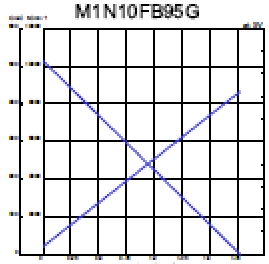
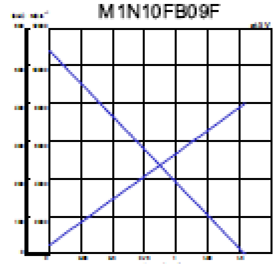


M1N10FB09F



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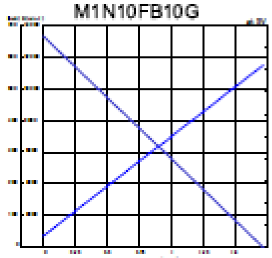

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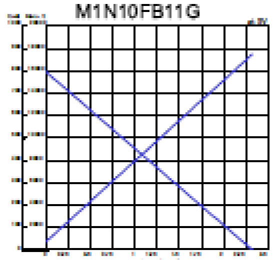


Thermoelectric Cooler

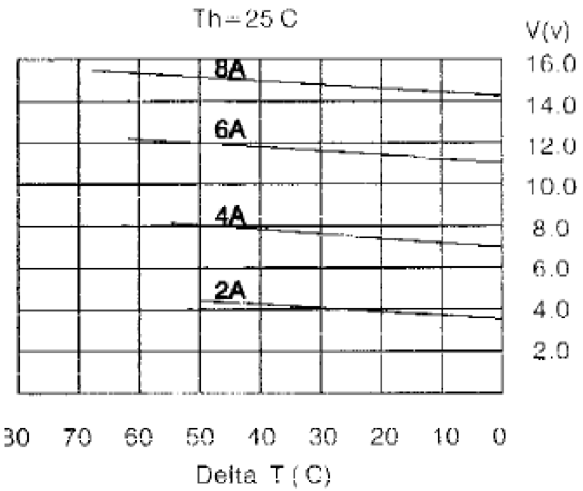
TEC1-12708

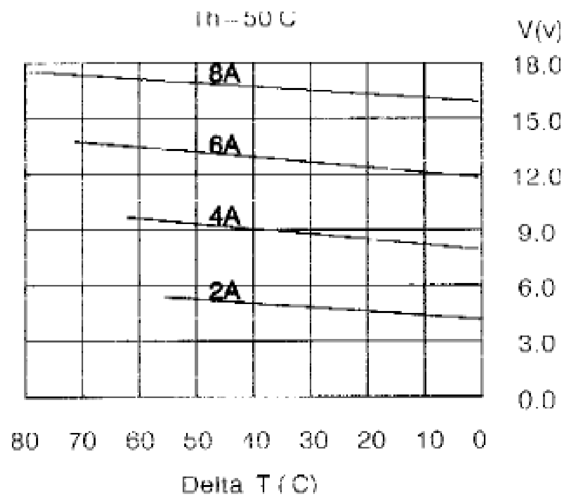
Performance Specifications

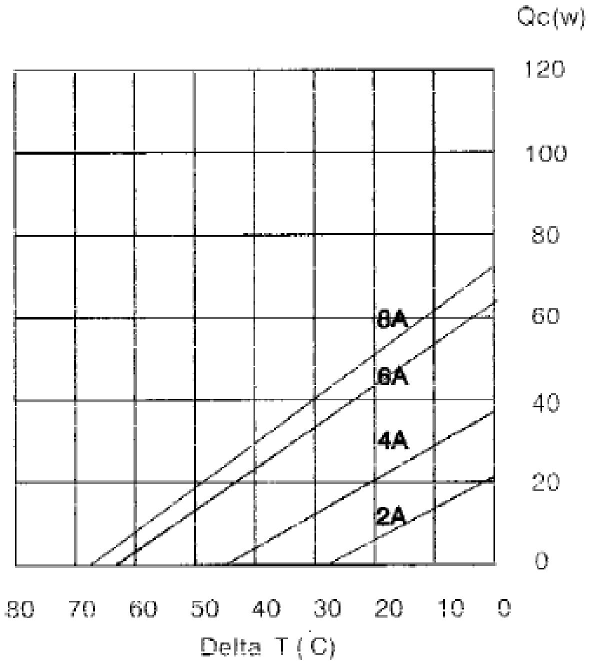
Hot Side Temperature (° C)	25° C	50° C
Qmax (Watts)	71	79
Delta Tmax (° C)	66	75
Imax (Amps)	8.5	8.4
Vmax (Volts)	15.4	17.5
Module Resistance (Ohms)	1.50	1.80

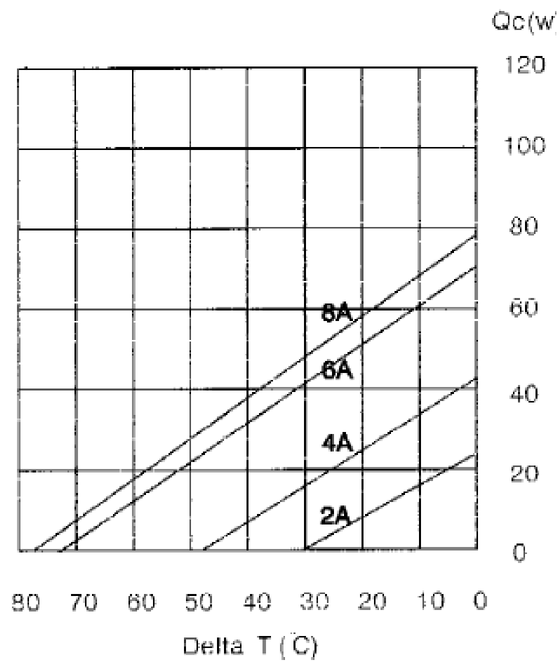
Performance curves on page 2

 Rev 2.03


Th=25 C
V(v)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
8A
6A
4A
2A
80 70 60 50 40 30 20 10 0
Delta T (C)

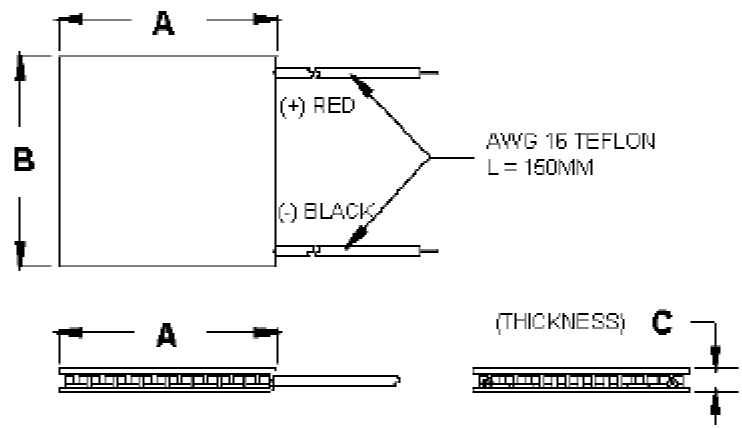

Th=50 C
V(v)
18.0
15.0
12.0
9.0
6.0
3.0
0.0
8A
6A
4A
2A
80 70 60 50 40 30 20 10 0
Delta T (C)


Qc(w)
120
100
80
60
40
20
0
8A
6A
4A
2A
80 70 60 50 40 30 20 10 0
Delta T (C)


Qc(w)
120
100
80
60
40
20
0
8A
6A
4A
2A
80 70 60 50 40 30 20 10 0
Delta T (C)

 Rev 2.03

TEC1-12708



Ceramic Material: Alumina (Al_2O_3)
Solder Construction: 138°C, Bismuth Tin (BiSn)

Size table:

A	B	C			
40	40	3.5			

Operating Tips

- Max. Operating Temperature: 138ºC
- Do not exceed Imax or Vmax when operating module.
- Life expectancy: 200,000 hours
-
- Please consult HB for moisture protection options (seeling).
- Failure rate based on long time testings: 0.2%.

bq2054

Lithium Ion Fast-Charge IC

Features

- Safe charge of Lithium Ion battery packs
- Voltage-regulated current-limited charging
- Fast charge terminated by selectable minimum current; safety backup termination on maximum time
- Charging continuously qualified by temperature and voltage limits
- Pulse-width modulation control ideal for high-efficiency switch-mode power conversion
- Direct LED control outputs display charge status and fault conditions

General Description

The bq2054 Lithium Ion Fast-Charge IC is designed to optimize charging of lithium ion (Li-Ion) chemistry batteries. A flexible pulse-width modulation regulator allows the bq2054 to control voltage and current during charging. The regulator frequency is set by an external capacitor for design flexibility. The switch-mode design keeps power dissipation to a minimum.

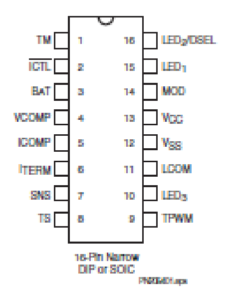
The bq2054 measures battery temperature using an external thermistor for charge qualification. Charging begins when power is applied or on battery insertion.

For safety, the bq2054 inhibits charging until the battery voltage and temperature are within configured limits. If the battery voltage is less than the low-voltage threshold, the bq2054 provides low-current conditioning of the battery.

A constant current-charging phase replenishes up to 70% of the charge capacity, and a voltage-regulated phase returns the battery to full. The charge cycle terminates when the charging current falls below a user-selectable current limit. For safety, charging terminates after maximum time and is suspended if the temperature is outside the preconfigured limits.

The bq2054 provides status indications of all charger states and faults for accurate determination of the battery and charge system conditions.

Pin Connections



Pin Names

TM	Time-out programming input	TPWM	Regulator timebase input
$\overline{ICTL}$	Inrush current control output	LED_3	Charge status output 3
BAT	Battery voltage input	LCOM	Common LED output
VCOMP	Voltage loop comp input	V_{SS}	System ground
ICOMP	Current loop comp input	V_{CC}	5.0V±10% power
I_{TERM}	Minimum current termination select input	MOD	Modulation control output
SNS	Sense resistor input	LED_1	Charge status output 1
TS	Temperature sense input	LED_2/DSEL	Charge status output 2/ Display select input

6/99 H

Pin Descriptions

TM **Time-out programming input**

This input sets the maximum charge time. The resistor and capacitor values are determined using Equation 5. Figure 7 shows the resistor/capacitor connection.

$\overline{\text{ICTL}}$ **Inrush current control output**

$\overline{\text{ICTL}}$ is driven low during the fault or charge-complete states of the chip. It is used to disconnect the capacitor across the battery pack terminals, preventing inrush currents from tripping overcurrent protection features in the pack when a new battery is inserted.

BAT **Battery voltage input**

BAT is the battery voltage sense input. This potential is generally developed using a high-impedance resistor divider network connected between the positive and the negative terminals of the battery. See Figure 4 and Equation 1.

VCOMP **Voltage loop compensation input**

This input uses an external R-C network for voltage loop stability.

I_{TERM} **Minimum current termination select**

This three-state input is used to set I_{MIN} for fast charge termination. See Table 2.

ICOMP **Current loop compensation input**

This input uses an external R-C network for current loop stability.

SNS **Charging current sense input**

Battery current is sensed via the voltage developed on this pin by an external sense resistor, R_{SNS}, connected in series with the negative terminal of the battery pack. See Equation 6.

TS **Temperature sense input**

This input is used to monitor battery temperature. An external resistor divider network sets the lower and upper temperature thresholds. See Figure 6 and Equations 3 and 4.

TPWM **Regulation timebase input**

This input uses an external timing capacitor to ground to set the pulse-width modulation (PWM) frequency. See Equation 7.

LCOM **Common LED output**

Common output for LED_{1-3}. This output is in a high-impedance state during initialization to read programming input on DSEL.

MOD **Current-switching control output**

MOD is a pulse-width modulated push/pull output that is used to control the charging current to the battery. MOD switches high to enable current flow and low to inhibit current flow.

LED_1–LED_3 **Charger display status 1–3 outputs**

These charger status output drivers are for the direct drive of the LED display. Display modes are shown in Table 1. These outputs are tri-stated during initialization so that DSEL can be read.

DSEL **Display select input**

This three-level input controls the LED_{1-3} charge display modes. See Table 1.

V_{CC} **V_{CC} supply**

5.0V, ± 10% power

V_{SS} **Ground**

Charge Algorithm

The bq2054 uses a two-phase fast charge algorithm. In phase 1, the bq2054 regulates constant current (I_{SNS} = I_{MAX}) until V_{CELL} (= V_{BAT} - V_{SNS}) rises to V_{REG}. The bq2054 then transitions to phase 2 and regulates constant voltage (V_{CELL} = V_{REG}) until the charging current falls below the programmed I_{MIN} threshold. The charging current must remain below I_{MIN} for 120 ± 40ms before a valid fast charge termination is detected. Fast charge then terminates, and the bq2054 enters the Charge Complete state. See Figures 1 and 2.

Charge Qualification

The bq2054 starts a charge cycle when power is applied while a battery is present or when a battery is inserted. Figure 2 shows the state diagram for pre-charge qualification and temperature monitoring. The bq2054 first checks that the battery temperature is within the allowed, user-configurable range. If the temperature is out of range, the bq2054 enters the Charge Pending state and waits until the battery temperature is within the allowed range. Charge Pending is enunciated by LED_3 flashing.

Thermal monitoring continues throughout the charge cycle, and the bq2054 enters the Charge Pending state when the temperature out of range. (There is one exception; if the bq2054 is in the Fault state—see below—the out-of-range temperature is not recognized until the bq2054 leaves the Fault state.) All timers are suspended (but not reset) while the bq2054 is in Charge Pending. When the temperature comes back into range, the bq2054 returns to the point in the charge cycle where the out-of-range temperature was detected.

When the temperature is valid, the bq2054 then regulates current to I_{COND} (=I_{MAX}/5). After an initial holdoff period t_{HO} (which prevents the chip from reacting to transient voltage spikes that may occur when charge current is first applied), the chip begins monitoring V_{CELL}. If V_{CELL} does not rise to at least V_{MIN} before the expiration of time-out limit t_{MTO} (e.g. the cell has failed short), the bq2054 enters the Fault state. If V_{MIN} is achieved before expiration of the time limit, the chip begins fast charging.

Once in the Fault state, the bq2054 waits until V_{CC} is cycled or a new battery insertion is detected. It then starts a new charge cycle and begins the qualification process again.

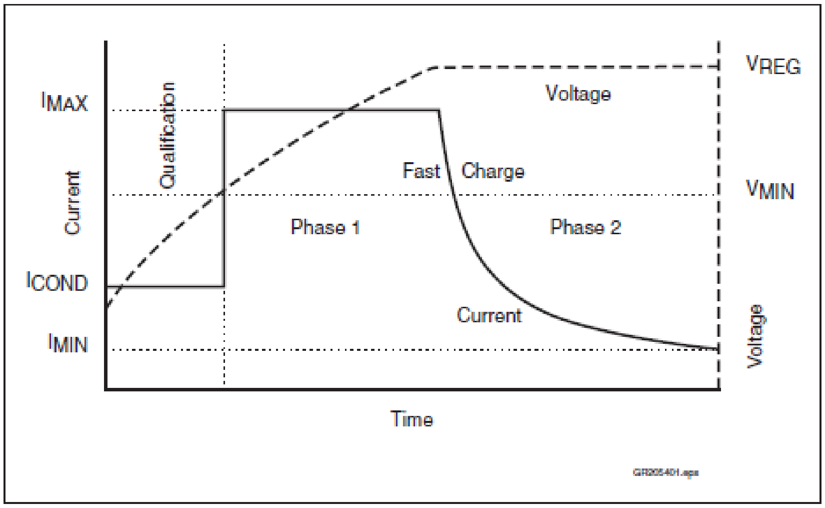


Figure 1. bq2054 Charge Algorithm

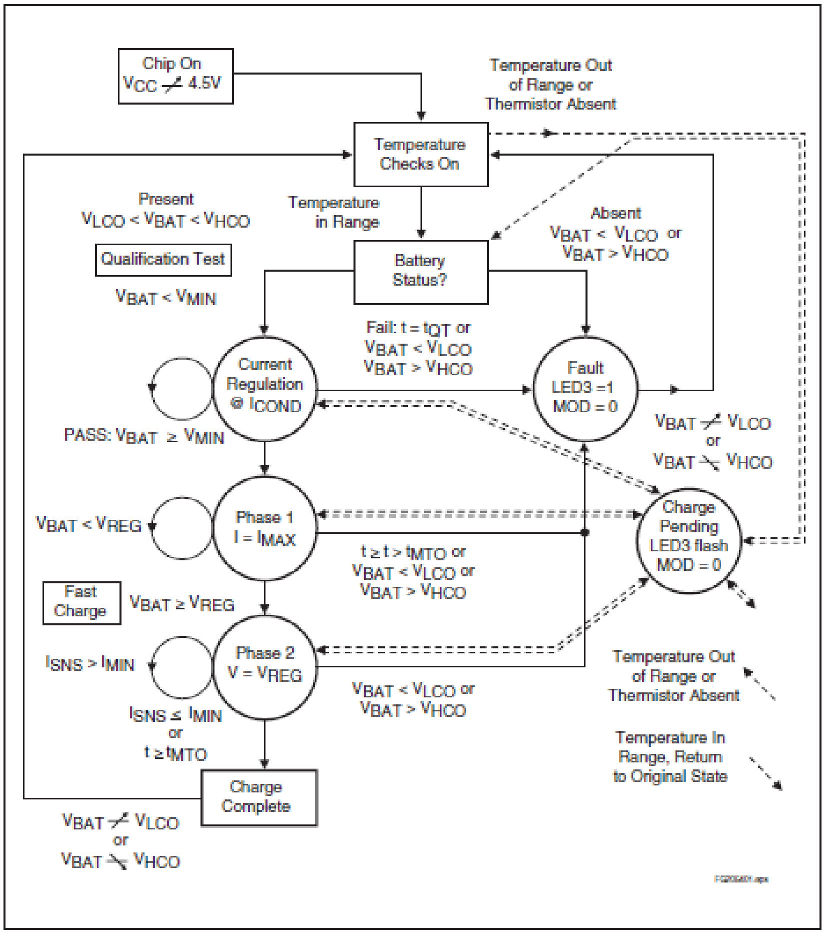


Figure 2. bq2054 State Diagram

Charge Status Display

Charge status is enunciated by the LED driver outputs LED_1–LED_3. Three display modes are available in the bq2054; the user selects a display mode by configuring pin DSEL. Table 1 shows the three display modes.

The bq2054 does not distinguish between an over-voltage fault and a "battery absent" condition. The bq2054 enters the Fault state, enunciated by turning on LED_3, whenever the battery is absent. The bq2054, therefore, gives an indication that the charger is on even when no battery is in place to be charged.

Configuring the Display Mode and I_{MIN}

DSEL/LED_2 is a bi-directional pin with two functions; it is an LED driver pin as an output and a programming pin as an input. The selection of pull-up, pull-down, or no pull resistor programs the display mode on DSEL per Table 1. The bq2054 latches the programming data sensed on the DSEL input when any one of the following three events occurs:

1. V_{CC} rises to a valid level.
2. The bq2054 leaves the Fault state.
3. The bq2054 detects battery insertion.

The LEDs go blank for approximately 750ms (typical) while new programming data is latched.

Table 1. bq2054 Display Output Summary

Mode	Charge Action State	LED_1	LED_2	LED_3
DSEL = 0 (Mode 1)	Battery absent or over-voltage fault	Low	Low	High
	Pre-charge qualification	Flash	Low	Low
	Fast charging	High	Low	Low
	Charge complete	Low	High	Low
	Charge pending (temperature out of range)	X	X	Flash
	Charging fault	X	X	High
DSEL = 1 (Mode 2)	Battery absent or over-voltage fault	Low	Low	High
	Pre-charge qualification	High	High	Low
	Fast charge	Low	High	Low
	Charge complete	High	Low	Low
	Charge pending (temperature out of range)	X	X	Flash
	Charging fault	X	X	High
DSEL = Float (Mode 3)	Battery absent or over-voltage fault	Low	Low	High
	Pre-charge qualification	Flash	Flash	Low
	Fast charge: current regulation	Low	High	Low
	Fast charge: voltage regulation	High	High	Low
	Charge complete	High	Low	Low
	Charge pending (temperature out of range)	X	X	Flash
	Charging fault	X	X	High

Note: 1 = V_{CC}; 0 = V_{SS}; X = LED state when fault occurred; Flash = ⅙ sec. low, ⅙ sec high.

Fast charge terminates when the charging current drops below a minimum current threshold programmed by the value of I_{TERM} (see Table 2) and remains below that level for 120 ± 40ms.

Table 2. I_{MIN} Termination Thresholds

I_{TERM}	I_{MIN}
0	$I_{MAX}/10$
1	$I_{MAX}/20$
Float	$I_{MAX}/30$

Figure 3 shows the bq2054 configured for display mode 2 and $I_{MIN} = I_{MAX}/10$.

Voltage and Current Monitoring

The bq2054 monitors battery pack voltage at the BAT pin. The user must implement a voltage divider between the positive and negative terminals of the battery pack to present a scaled battery pack voltage to the BAT pin. The bq2054 also uses the voltage across a sense resistor (R_{SNS}) between the negative terminal of the battery pack and ground to monitor the current into the pack. See Figure 4 for the configuration of this network.

The resistor values are calculated from the following:

Equation 1

$$\frac{RB1}{RB2} = \frac{N * V_{REG}}{2.05V} - 1$$

where:

- N = Number of cells in series
- V_{REG} = Desired fast-charging voltage per cell

These parameters are typically specified by the battery manufacturer. The total resistance presented across the battery pack by RB1 + RB2 should be between 150kΩ and 1MΩ. The minimum value ensures that the divider network does not drain the battery excessively when the power source is disconnected. Exceeding the maximum value increases the noise susceptibility of the BAT pin.

The current sense resistor, R_{SNS} (see Figure 5), determines the fast charge current. The value of R_{SNS} is given by the following:

Equation 2

$$I_{MAX} = \frac{0.250V}{R_{SNS}}$$

where:

- I_{MAX} = Desired maximum charge current

Hold-Off Period

Both V_{HCO} and I_{MIN} terminations are ignored during the first 1.33 ± 0.19 seconds of both the Charge Qualification and Fast Charge phases. This condition prevents premature termination due to voltage spikes that may occur when charge is first applied.

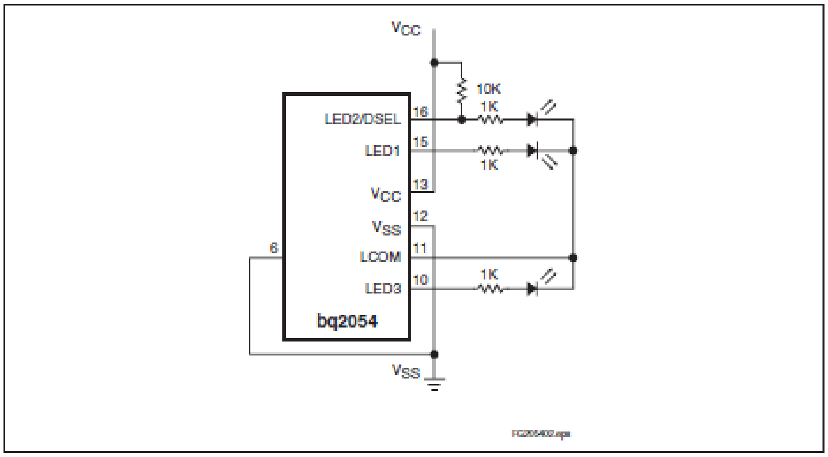


Figure 3. Configured Display Mode/IMIN Threshold

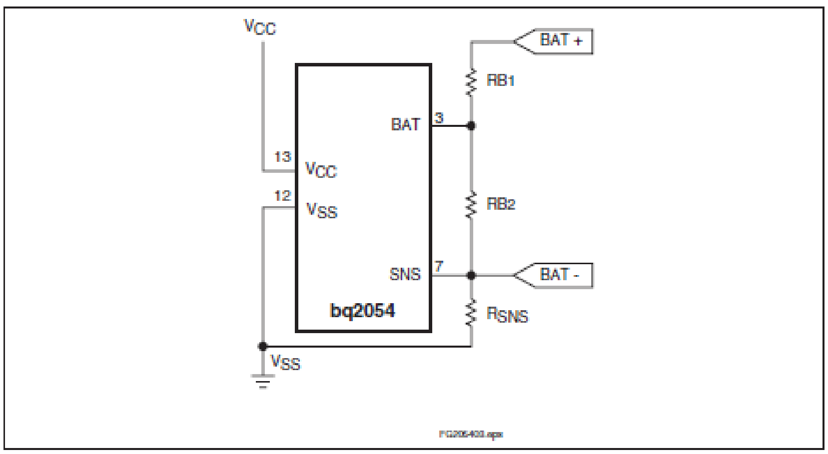


Figure 4. Configuring the Battery Divider

Battery Insertion and Removal

V_{CELL} is interpreted by the bq2054 to detect the presence or absence of a battery. The bq2054 determines that a battery is present when V_{CELL} is between the High-Voltage Cutoff ($V_{HCO} = V_{REG} + 0.25V$) and the Low-Voltage Cutoff ($V_{LCO} = 0.8V$). When V_{CELL} is outside this range, the bq2054 determines that no battery is present and transitions to the Fault state. Transitions into and out of the range between V_{LCO} and V_{HCO} are treated as battery insertions and removals, respectively. The V_{HCO} limit also implicitly serves as an overvoltage charge termination.

Inrush Current Control

Whenever the bq2054 is in the fault or charge-complete state, the $\overline{ICTL}$ output is driven low. This output can be used to disconnect the capacitor usually present in the charger across the positive and negative battery terminals, preventing the cap from supplying large inrush currents to a newly inserted battery. Such inrush currents may trip the overcurrent protection circuitry usually present in Li-Ion battery packs.

Temperature Monitoring

The bq2054 monitors temperature by examining the voltage presented between the TS and SNS pins by a resistor network that includes a Negative Temperature Coefficient (NTC) thermistor. Resistance variations around that value are interpreted as being proportional to the battery temperature (see Figure 6).

The temperature thresholds used by the bq2054 and their corresponding TS pin voltage are:

- TCO (Temperature Cutoff): Higher limit of the temperature range in which charging is allowed. $V_{TCO} = 0.4 * V_{CC}$
- HTF (High-Temperature Fault): Threshold to which temperature must drop after temperature cutoff is exceeded before charging can begin again. $V_{HTF} = 0.44 * V_{CC}$
- LTF (Low-Temperature Fault): Lower limit of the temperature range in which charging is allowed. $V_{LTF} = 0.6 * V_{CC}$

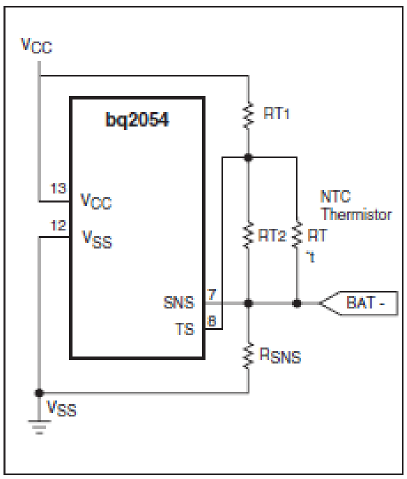


Figure 5. Configuring Temperature Sensing

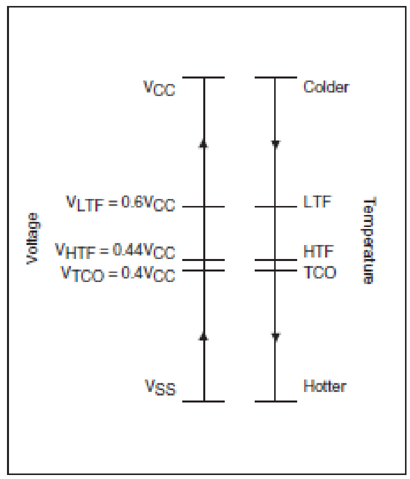


Figure 6. Voltage Equivalent of Temperature

A resistor-divider network can be implemented that presents the defined voltage levels to the TS pin at the desired temperatures (see Figure 6).

The equations for determining RT1 and RT2 are:

Equation 3

$$0.6 * V_{CC} = \frac{(V_{CC} - 0.250)}{1 + \frac{RT1 * (RT2 + R_{LTF})}{(RT2 * R_{LTF})}}$$

Equation 4

$$0.44 = \frac{1}{1 + \frac{RT1 * (RT2 + R_{HTF})}{(RT2 * R_{HTF})}}$$

where:

- R_{LTF} = thermistor resistance at LTF
- R_{HTF} = thermistor resistance at HTF

TCO is determined by the values of RT1 and RT2. 1% resistors are recommended.

Disabling Temperature Sensing

Temperature sensing can be disabled by placing 10kΩ resistors between TS and SNS and between SNS and V_{CC}.

Maximum Time-Out

MTO is programmed from 1 to 24 hours by an R-C network on the TM pin (see Figure 7) per the equation:

Equation 5

$$t_{MTO} = 0.5 * R * C$$

Where R is in kΩ and C is in µF, t_{MTO} is in hours. The maximum value for C (0.1µF) is typically used.

The MTO timer is reset at the beginning of fast charge and when fast charge transitions from the current regulated to the voltage regulated mode. If MTO expires during the current regulated phase, the bq2054 enters the Fault state and terminates charge. If the MTO timer expires during the voltage regulated phase, fast charging terminates and the bq2054 enters the Charge Complete state.

The MTO timer is suspended (but not reset) during the out-of-range temperature (Charge Pending) state.

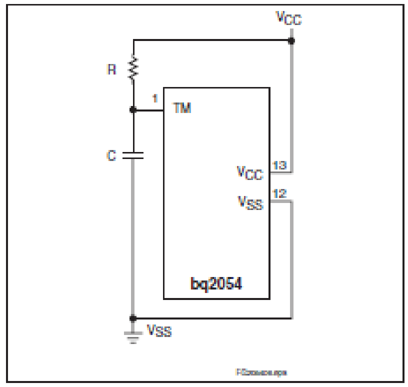


Figure 7. R-C Network for Setting MTO

Charge Regulation

The bq2054 controls charging through pulse-width modulation of the MOD output pin, supporting both constant-current and constant-voltage regulation. Charge current is monitored at the SNS pin, and charge voltage is monitored at the BAT pin. These voltages are compared to an internal reference, and the MOD output modulated to maintain the desired value.

Voltage at the SNS pin is determined by the value of resistor R_{SNS}, so nominal regulated current is set by:

Equation 6

$$I_{MAX} = 0.250V/R_{SNS}$$

The switching frequency of the MOD output is determined by an external capacitor (CPWM) between the pin TPWM and ground, per the following:

Equation 7

$$F_{PWM} = 0.1/C_{PWM}$$

Where C is in µF and F is in kHz. A typical switching rate is 100kHz, implying C_{PWM} = 0.001µF. MOD pulse width is modulated between 0 and 90% of the switching period.

To prevent oscillation in the voltage and current control loops, frequency compensation networks (C or R-C) are typically required on the V_{COMP} and I_{COMP} pins (respectively).

Absolute Maximum Ratings

Symbol	Parameter	Minimum	Maximum	Unit	Notes
V_{CC}	V_{CC} relative to V_{SS}	-0.3	+7.0	V	
V_T	DC voltage applied on any pin excluding V_{CC} relative to V_{SS}	-0.3	+7.0	V	
T_{OPR}	Operating ambient temperature	-20	+70	°C	Commercial
T_{STG}	Storage temperature	-55	+125	°C	
T_{SOLDER}	Soldering temperature	-	+260	°C	10 sec. max.

Note: Permanent device damage may occur if **Absolute Maximum Ratings** are exceeded. Functional operation should be limited to the Recommended DC Operating Conditions detailed in this data sheet. Exposure to conditions beyond the operational limits for extended periods of time may affect device reliability.

DC Thresholds (TA = TOPR; VCC = 5V ±10%)

Symbol	Parameter	Rating	Unit	Tolerance	Notes
V_{REF}	Internal reference voltage	2.05	V	1%	$T_A = 25°C$
	Temperature coefficient	-0.5	mV/°C	10%	
V_{LTF}	TS maximum threshold	0.6 * V_{CC}	V	±0.03V	Low-temperature fault
V_{HTF}	TS hysteresis threshold	0.44 * V_{CC}	V	±0.03V	High-temperature fault
V_{TCO}	TS minimum threshold	0.4 * V_{CC}	V	±0.03V	Temperature cutoff
V_{HCO}	High cutoff voltage	2.3V	V	1%	
V_{MIN}	Under-voltage threshold at BAT	0.2 * V_{CC}	V	±0.03V	
V_{LCO}	Low cutoff voltage	0.8	V	±0.03V	
V_{SNS}	Current sense at SNS	0.250	V	10%	I_{MAX}
		0.050	V	10%	I_{COND}

Recommended DC Operating Conditions ($T_A = T_{OPR}$)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
V_{CC}	Supply voltage	4.5	5.0	5.5	V	
V_{TEMP}	Temperature sense voltage	0	-	V_{CC}	V	V_{TS} - V_{SNS}
V_{CELL}	Per cell battery voltage input	0	-	V_{CC}	V	V_{BAT} - V_{SNS}
I_{CC}	Supply current	-	2	4	mA	Outputs unloaded
I_{IZ}	DSEL tri-state open detection	-2	-	2	µA	Note 2
	I_{TERM} tri-state open detection	-2		2	µA	
V_{IH}	Logic input high	V_{CC}-0.3	-	-	V	DSEL, I_{TERM}
V_{IL}	Logic input low	-	-	V_{SS}+0.3	V	DSEL, I_{TERM}
V_{OH}	LED_{1-3}, $\overline{ICTL}$, output high	V_{CC}-0.8	-	-	V	$I_{OH} \leq$ 10mA
	MOD output high	V_{CC}-0.8	-	-	V	$I_{OH} \leq$ 10mA
V_{OL}	LED_{1-3}, $\overline{ICTL}$, output low	-	-	V_{SS}+0.8V	V	$I_{OL} \leq$ 10mA
	MOD output low	-	-	V_{SS}+0.8V	V	$I_{OL} \leq$ 10mA
	LCOM output low	-	-	V_{SS}+0.5	V	$I_{OL} \leq$ 30mA
I_{OH}	LED_{1-3}, $\overline{ICTL}$, source	-10	-	-	mA	V_{OH} =V_{CC}-0.5V
	MOD source	-5.0	-	-	mA	V_{OH} =V_{CC}-0.5V
I_{OL}	LED_{1-3}, $\overline{ICTL}$, sink	10	-	-	mA	V_{OL} = V_{SS}+0.5V
	MOD sink	5	-	-	mA	V_{OL} = V_{SS}+0.8V
	LCOM sink	30	-	-	mA	V_{OL} = V_{SS}+0.5V
I_{IL}	DSEL logic input low source	-	-	+30	µA	V = V_{SS} to V_{SS}+ 0.3V, Note 2
	I_{TERM} logic input low source	-	-	+70	µA	V = V_{SS} to V_{SS}+ 0.3V
I_{IH}	DSEL logic input high source	-30	-	-	µA	V = V_{CC} - 0.3V to V_{CC}
	I_{TERM} logic input high source	-70	-	-	µA	V = V_{CC} - 0.3V to V_{CC}

Notes:
1. All voltages relative to V_{SS} except where noted.
2. Conditions during initialization after V_{CC} applied.

Impedance

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
R_{BATZ}	BAT pin input impedance	50	-	-	MΩ	
R_{SNSZ}	SNS pin input impedance	50	-	-	MΩ	
R_{TSZ}	TS pin input impedance	50	-	-	MΩ	
R_{PROG1}	Soft-programmed pull-up or pull-down resistor value (for programming)	-	-	10	kΩ	DSEL
R_{PROG2}	Pull-up or pull-down resistor value	-	-	3	kΩ	I_{TERM}
R_{MTO}	Charge timer resistor	20	-	480	kΩ	

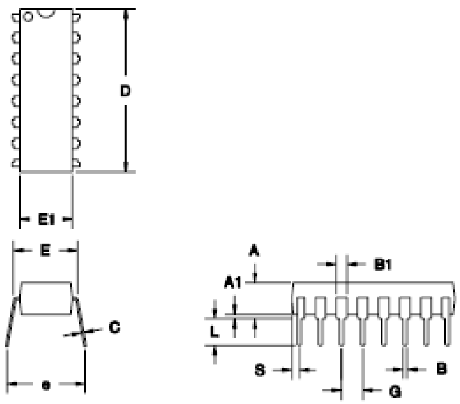
Timing (TA = TOPR; VCC = 5V ±10%)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
t_{MTO}	Charge time-out range	1	-	24	hours	See Figure 7
t_{QT}	Pre-charge qual test time-out period	-	t_{MTO}	-	-	
t_{HO}	Termination hold-off period	1.14	-	1.52	sec.	
t_{IMIN}	Min. current detect filter period	80		160	msec.	
F_{PWM}	PWM regulator frequency range	-	100		kHz	C_{PWM} = 0.001µF (equation 7)

Capacitance

Symbol	Parameter	Minimum	Typical	Maximum	Unit
C_{MTO}	Charge timer capacitor	-	-	0.1	µF
C_{PWM}	PWM R-C capacitance	-	0.001	-	µF

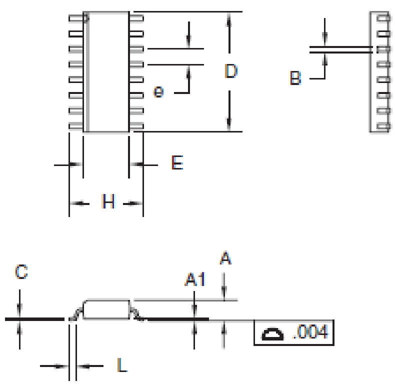
16-Pin DIP Narrow (PN)



16-Pin PN (0.300" DIP)

Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	0.160	0.180	4.06	4.57
A1	0.015	0.040	0.38	1.02
B	0.015	0.022	0.38	0.56
B1	0.055	0.065	1.40	1.65
C	0.008	0.013	0.20	0.33
D	0.740	0.770	18.80	19.56
E	0.300	0.325	7.62	8.26
E1	0.230	0.280	5.84	7.11
e	0.300	0.370	7.62	9.40
G	0.090	0.110	2.29	2.79
L	0.115	0.150	2.92	3.81
S	0.020	0.040	0.51	1.02

16-Pin SOIC Narrow (SN)



16-Pin SN (0.150" SOIC)

Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	0.060	0.070	1.52	1.78
A1	0.004	0.010	0.10	0.25
B	0.013	0.020	0.33	0.51
C	0.007	0.010	0.18	0.25
D	0.385	0.400	9.78	10.16
E	0.150	0.160	3.81	4.06
e	0.045	0.055	1.14	1.40
H	0.225	0.245	5.72	6.22
L	0.015	0.035	0.38	0.89

Data Sheet Revision History

Change No.	Page No.	Description	Nature of Change
1	5, 7, 8, 10	Value Change	Changed V_{SNS} and I_{MAX}
2	5, 10	Value Change	Changed V_{REF}
3	10	Coefficient Addition	Temperature coefficient added
4	5	New state diagram	Diagram inserted
4	1, 2, 8, 12	NC pin replaced with $\overline{ICTL}$	
4	3, 5, 13	Termination hold-off period added I_{MIN} detect filtering added	
5	11	V_{HCO} Rating changed to 2.3V V_{HCO} Tolerance changed to 1%	Changed values for V_{HCO}
6	13	t_{QT} in Timing Specifications	t_{QT} changed from (0.16 * t_{MTO}) to t_{MTO}
7	5	I_{TERM} in Table 2	Z changes to Float
7	8	Figure 6	RB1 and RB2 changed to RT1 and RT2
8	10	T_{OPR}	Deleted industrial temperature range.

Notes: Change 3 = April 1996 C changes from Dec. 1995 B.
Change 4 = Sept. 1996 D changes from April 1996 C.
Change 5 = Nov. 1996 E changes from Sept. 1996 D.
Change 6 = Oct. 1997 F changes from Nov. 1996 E.
Change 7 = Oct. 1997 G changes from Oct. 1997 F.
Change 8 = June 1999 H changes from Oct. 1997 G.

Ordering Information

bq2054

Package Option:
PN = 16-pin plastic DIP
SN = 16-pin narrow SOIC

Device:
bq2054 Li-Ion Fast-Charge IC

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
BQ2054PN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
BQ2054PNE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
BQ2054SN	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ2054SNG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ2054SNTR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ2054SNTRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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![ROHM SEMICONDUCTOR] Data Sheet

100VAC Input/5VDC (100mA) Output

Non-Isolated AC/DC Converter

BP5034D5

● Absolute Maximum Ratings

Parameter	Symbol	Limits	Unit
Input voltage	Vi	195	V
Output current	Io	100	mApk
ESD endurance	Vsurge	2	kV
Operating temperature range	Topr	−20 to +80	°C
Storage temperature range	Tstg	−25 to +85	°C

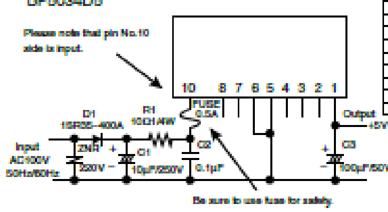
● Electrical Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Input voltage range	Vi	113	141	195	V	DC(80 to 138VAC)
Output voltage	Vo	4.7	5.0	5.3	V	Vi=141V, Io=50mA
Output current	Io	0	−	100	mA	Vi=141V *1
Line regulation	Vr	−	0.02	0.1	V	Vi=113 to 195V, Io=50mA
Load regulation	Vl	−	0.05	0.15	V	Vi=141V, Io=0 to 50mA *2
Output ripple voltage	Vp	−	0.05	0.15	Vp-p	Vi=141V, Io=50mA
Power conversion efficiency	η	49	56	−	%	Vi=141V, Io=100mA *2

*1 Maximum output current varies depending on ambient temperature ; please refer to derating curve.
*2 Please refer to Load regulation, Conversion efficiency.

● Application Circuit

BP5034D5



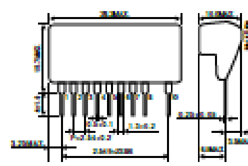
Pin No.	Function
1	Output terminal Vo(5V)
2	N.C.
3	N.C.
4	N.C.
5	COMMON
6	COMMON
7	N.C.
8	N.C.
9	Stopping pin
10	Input terminal Vi(141VDC)

Please verify operation and characteristics in the customer's circuit before actual usage.
Ensure that the load current does not exceed the maximum rating.

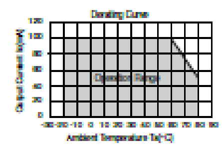
External Component Specifications

FUSE: Fuse	Use a quick-acting fuse of 0.5A
C1: Input smoothing capacitor	Capacitance : 3.3 to 22μF Rated voltage : 250V or higher
C2: Noise reduction capacitor	Capacitance : 0.1 to 0.22μF Rated voltage : 250V or higher Use a film or ceramic capacitor. Evaluate under actual operating conditions.
C3: Output smoothing capacitor	Capacitance : 100 to 470μF Rated voltage : 25V or higher, low impedance Impedance is 0.39Ω max at high frequencies Ripple current is 0.1Arms or above. Capacitor impedance affects the output ripple voltage.
D1: Rectifier diode	In the absolute maximum ratings, the reverse surge voltage should be 400V or higher, the average rectifying current should be 0.5A or higher, and the forward surge current should be 20A or higher.
R1: Noise reduction resistor	10 to 22Ω, 1/4W The ideal value should be determined through actual testing.
ZNR: Varistor	A varistor must be used to protect against lightning surges and static electricity.

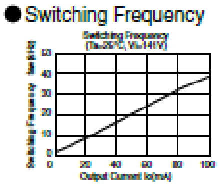
● Dimensions (Unit : mm)



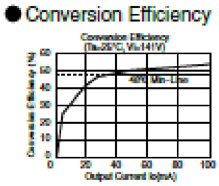
● Derating Curve



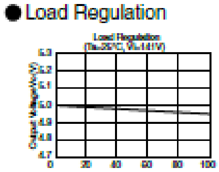
● Switching Frequency



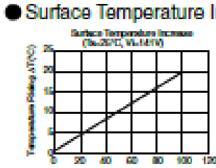
● Conversion Efficiency



● Load Regulation



● Surface Temperature Increase



Power Module Usage Precautions

Safety Precautions

1) The products are designed and manufactured for use in ordinary electronic equipment (i.e. AV/OA/ telecommunication/amusement equipment, home appliances). Please consult with the Company's (ROHM) sales staff if intended for use in devices requiring high reliability (e.g. medical/transport/ aircraft/spacecraft equipment, nuclear power/fuel controllers, automotive/safety devices) and whose malfunction may result in injury or death. In this case, failsafe measures must be taken, including the following:
   [a] Installation of protection circuits in order to improve system safety
   [b] Incorporation of redundant circuits in the case of single-circuit failure
2) The products are designed for use under normal conditions. Application in special environments can cause a deterioration in product performance. Therefore, verification and confirmation of product performance, prior to use, is recommended. The following environments are considered to be 'special':
   [a] Outdoors, exposed to direct sunlight or dust
   [b] In contact with liquids, such as water, oils, chemicals, or organic solvents
   [c] In areas where exposure to the sea air or corrosive gases (i.e. Cl_2, H_2S, NH_3, SO_2, NO_2) can occur
   [d] In places where the products may be in contact with static electricity or electromagnetic waves
   [e] In proximity to heat-producing items, plastic cords, or flammable materials
   [f] In contact with sealing or coating products, such as resin
   [g] In contact with unclean solder or exposed to water or water-soluble cleaning agents used after soldering
   [h] In areas where dew condensation occurs
3) The products are not designed to be radiation resistant
4) The Company is not responsible for any problems resulting from use of the products under conditions not recommended herein.
5) The Company should be notified of any product safety issues. Moreover, product safety issues should be periodically monitored by the customer.

Application Notes

1) A sufficient margin must be allowed if changes are made to the peripheral circuit due to variations in the inherent tolerances of the external components as well as transient and static characteristics. In addition, please be aware that the Company has not conducted investigations on whether or not particular changes in the example application circuits would result in patent infringement.
2) The application examples, their constants, and other types of information contained herein are applicable only when the products are used in accordance with standard methods.
   Therefore, if mass production is intended, sufficient consideration to external conditions must be made.

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   [a] Infringement of the intellectual property rights of a third party
   [b] Problems arising from the use of the products listed herein
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